US008312088B2

(12) **United States Patent**
Pinto

(10) **Patent No.: US 8,312,088 B2**
(45) **Date of Patent: Nov. 13, 2012**

(54) **DEVICE IDENTIFIER SELECTION**

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(73) Assignee: **Sandisk IL Ltd.**, Kfar Saba (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 458 days.

(21) Appl. No.: **12/561,122**

(22) Filed: **Sep. 16, 2009**

(65) **Prior Publication Data**

US 2011/0022666 A1 Jan. 27, 2011

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/509,832, filed on Jul. 27, 2009.

(51) **Int. Cl.**
G06F 15/16 (2006.01)

(52) **U.S. Cl.** **709/206**; 709/224; 709/238

(58) **Field of Classification Search** 709/223–224, 709/238, 251, 206
See application file for complete search history.

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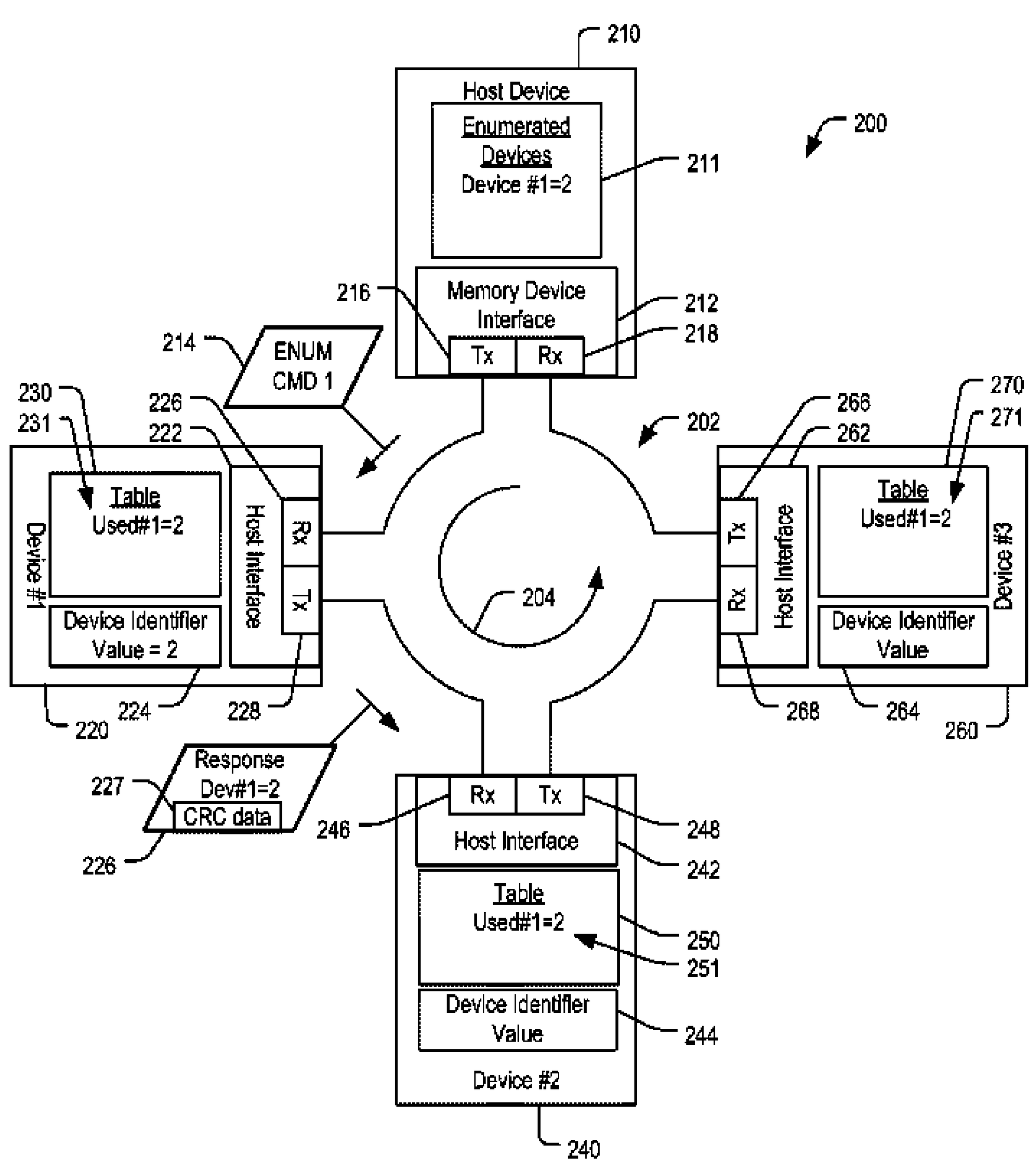
(74) *Attorney, Agent, or Firm* — Toler Law Group, PC

(57) **ABSTRACT**

Systems and methods of device identifier selection are disclosed. In a particular embodiment, a method includes, at a hub device having a plurality of ports including a first port, a second port, and a third port, receiving a first message from a host device. The first message including a broadcast indicator. The method also includes, in response to determining that the first message requests enumeration, emulating a ring communication topology by serially propagating messages including an enumeration indicator to a first device via the first port and to a second device via the second port. The method further includes, in response to determining that the first message does not request enumeration, selectively sending the first message to the first device substantially concurrently with sending the first message to the second device. Emulating the ring communication topology enables the hub device to provide a first distinctive identifier value of the first device and a second distinctive identifier value of the second device to the host device.

36 Claims, 27 Drawing Sheets



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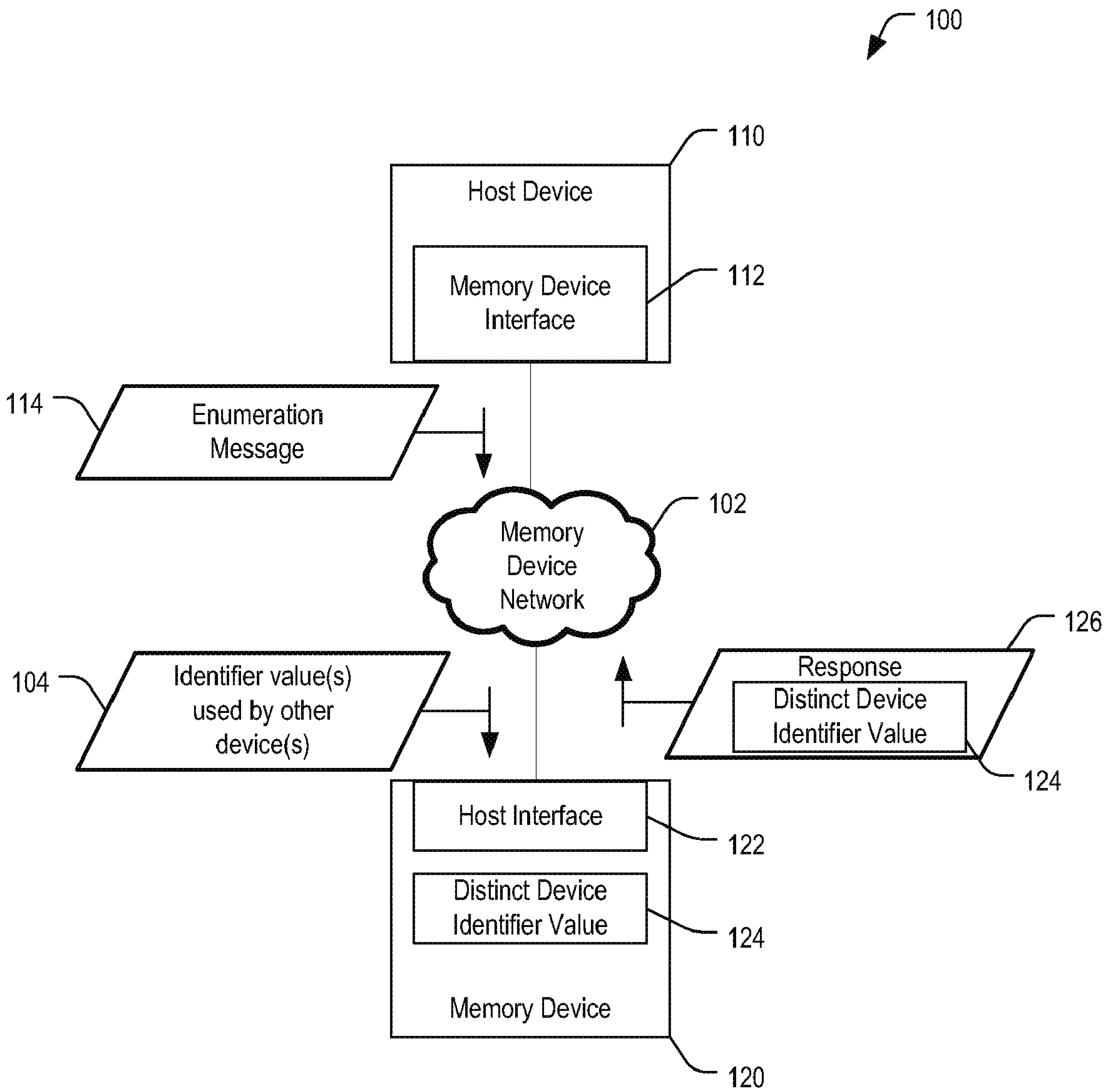


100
110
Host Device
Memory Device Interface
112
114
Enumeration Message
Memory Device Network
102
126
Response
Distinct Device Identifier Value
104
Identifier value(s) used by other device(s)
124
Host Interface
122
Distinct Device Identifier Value
124
Memory Device
120

FIG. 1

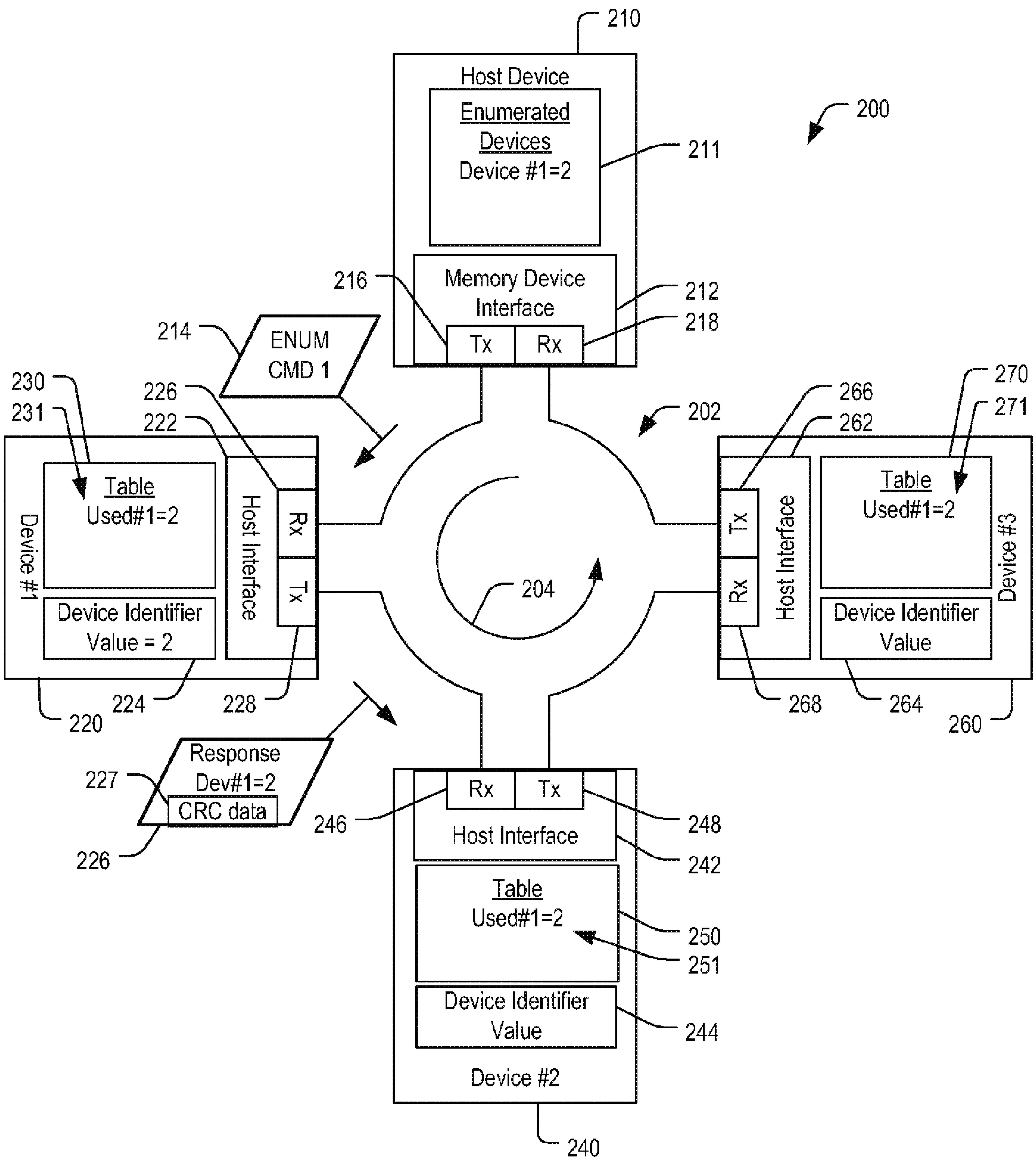

210
Host Device
Enumerated Devices
Device #1=2
211
200
216
Memory Device Interface
212
218
Tx
Rx
214
ENUM CMD 1
230
231
226
222
266
262
270
271
202
Table
Used#1=2
Device #1
Host Interface
Rx
Tx
Device Identifier Value = 2
204
Tx
Rx
Host Interface
Table
Used#1=2
Device #3
Device Identifier Value
224
228
220
268
264
260
227
Response
Dev#1=2
CRC data
226
246
Rx
Tx
Host Interface
248
242
Table
Used#1=2
250
251
Device Identifier Value
244
Device #2
240

FIG. 2

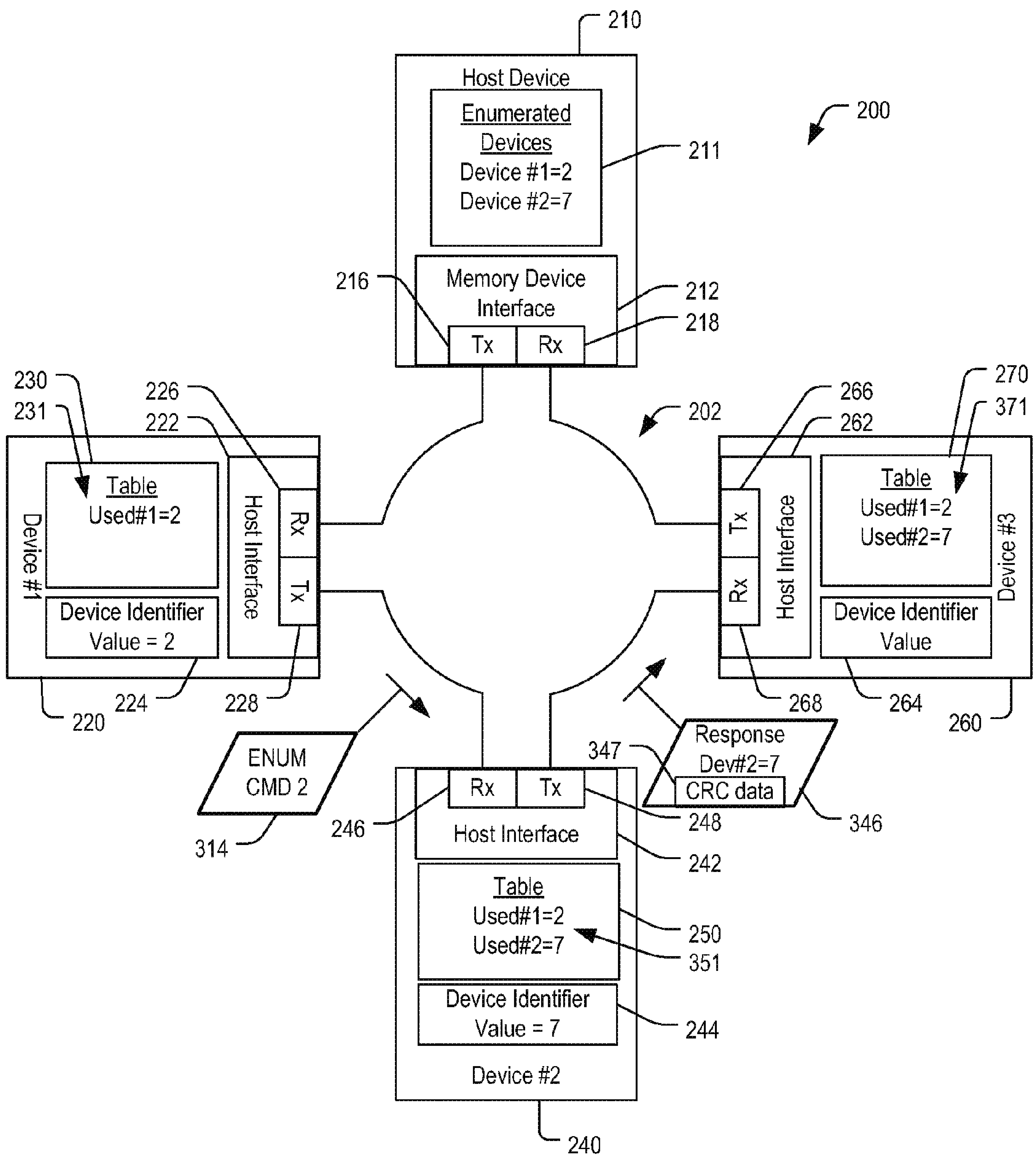
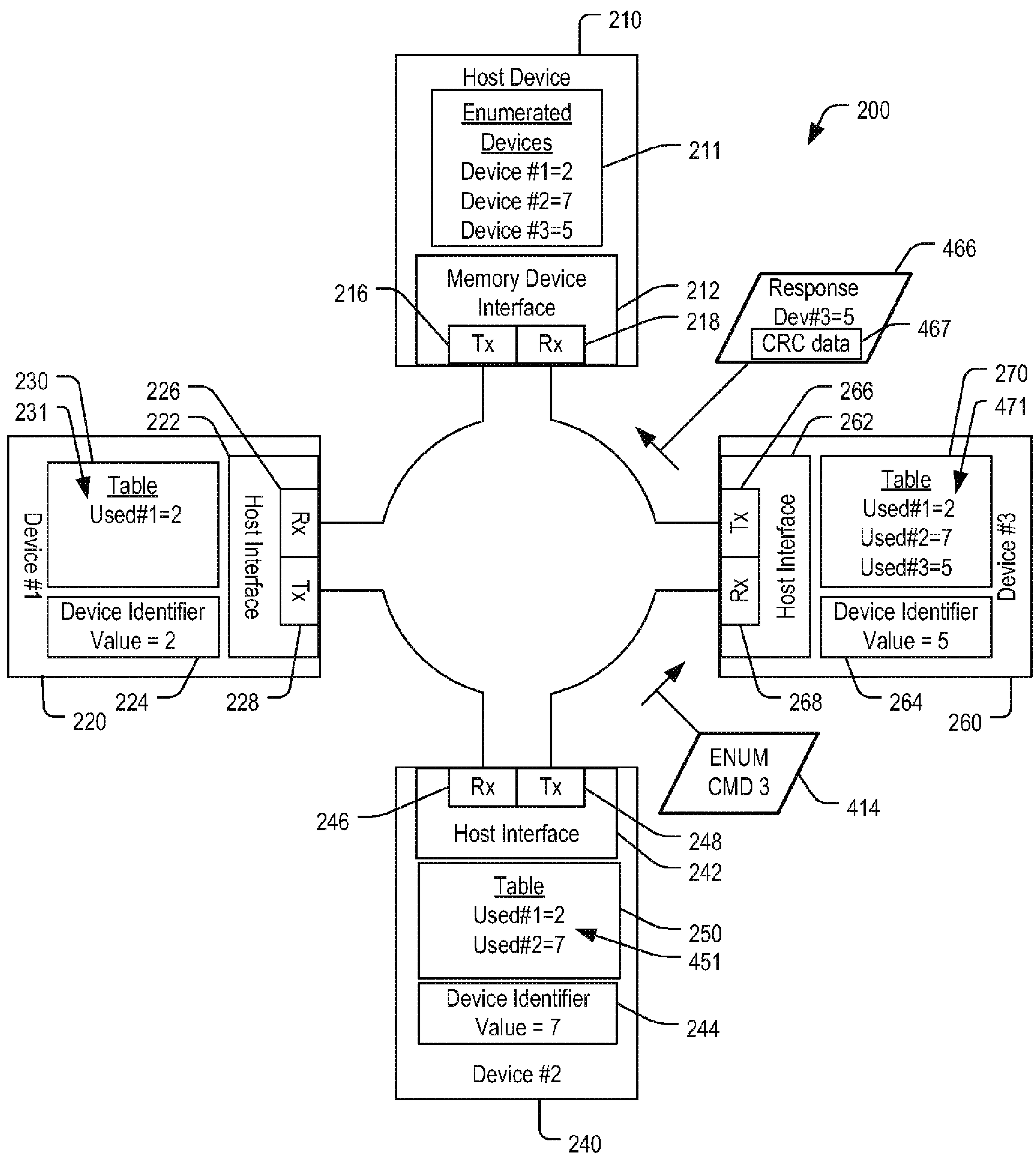
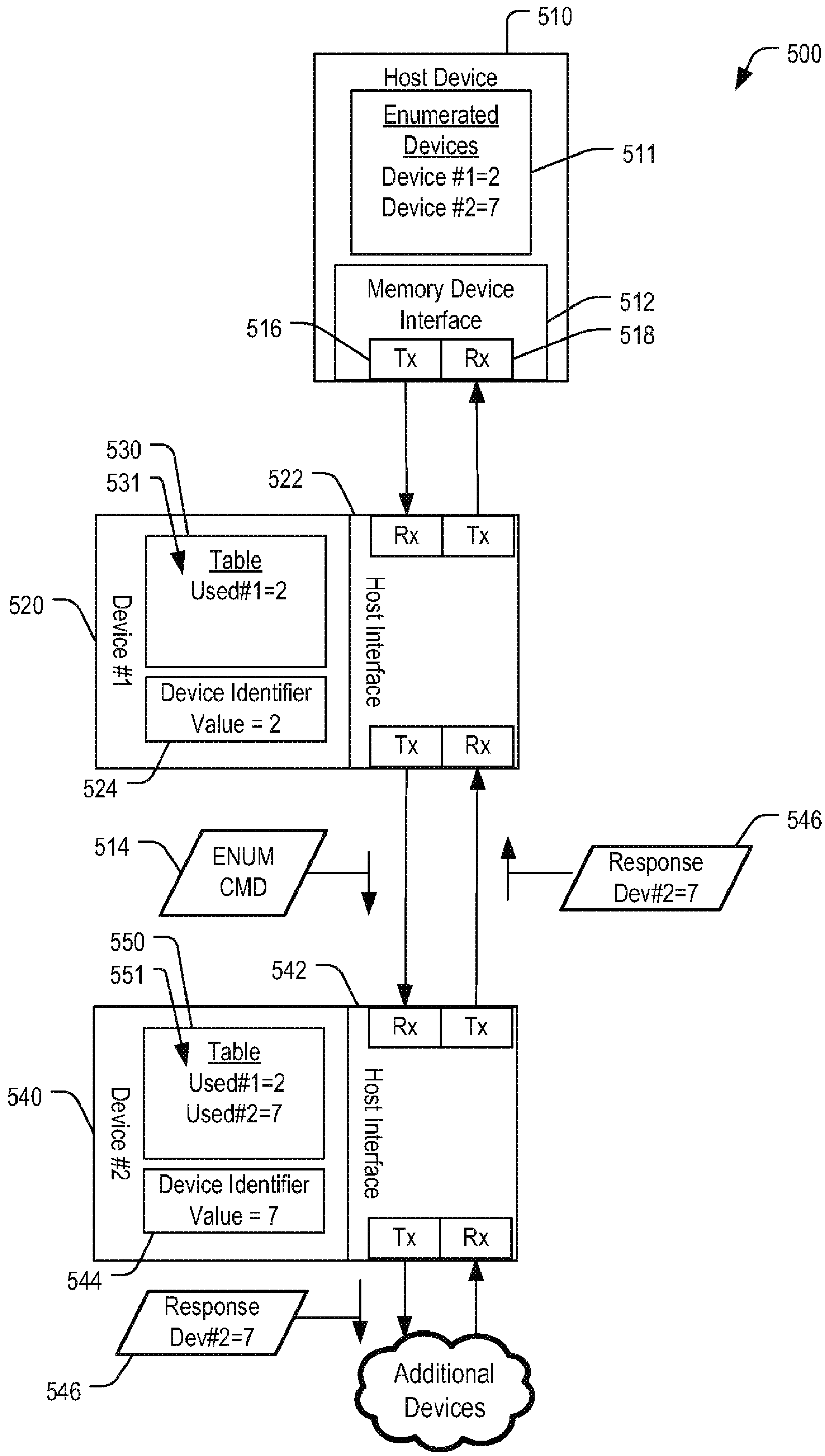

210
Host Device
Enumerated Devices
Device #1=2
Device #2=7
211
200
216
Memory Device Interface
212
218
Tx
Rx
230
231
226
222
202
266
262
270
371
Table
Used#1=2
Device #1
Host Interface
Rx
Tx
Device Identifier Value = 2
224
228
220
Tx
Rx
Host Interface
Table
Used#1=2
Used#2=7
Device #3
Device Identifier Value
268
264
260
ENUM CMD 2
314
246
347
Response Dev#2=7
CRC data
346
Rx
Tx
248
Host Interface
242
Table
Used#1=2
Used#2=7
250
351
Device Identifier Value = 7
244
Device #2
240

FIG. 3



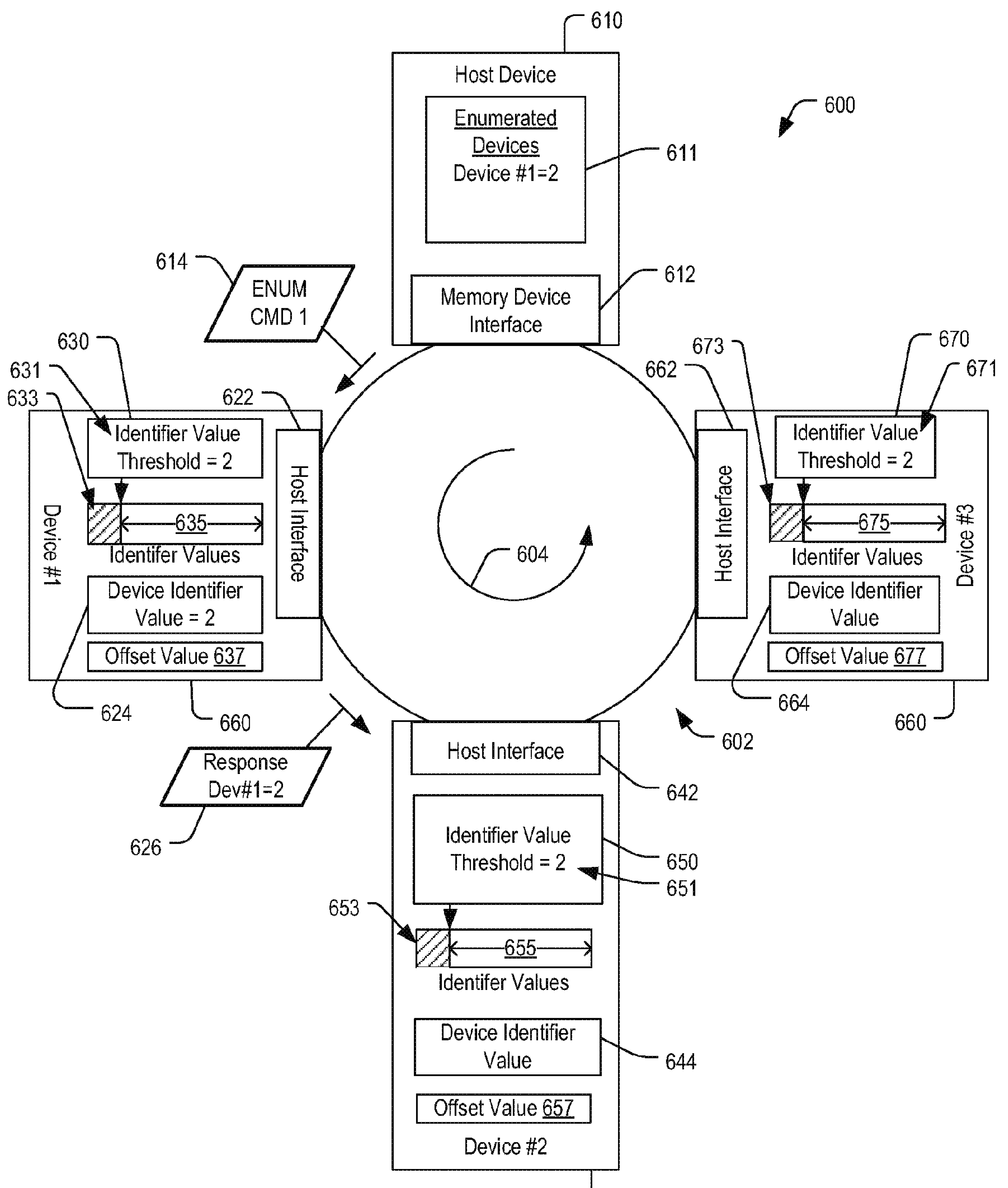
210
Host Device
Enumerated Devices
Device #1=2
Device #2=7
Device #3=5
211
200
Memory Device Interface
216
212
218
Tx
Rx
466
Response
Dev#3=5
CRC data
467
230
231
226
222
Table
Used#1=2
Device #1
Host Interface
Rx
Tx
Device Identifier
Value = 2
224
228
220
266
262
270
471
Tx
Rx
Host Interface
Table
Used#1=2
Used#2=7
Used#3=5
Device #3
Device Identifier
Value = 5
268
264
260
ENUM
CMD 3
414
Rx
Tx
246
Host Interface
248
242
Table
Used#1=2
Used#2=7
250
451
Device Identifier
Value = 7
244
Device #2
240

FIG. 4



510
500
Host Device
Enumerated Devices
Device #1=2
Device #2=7
511
Memory Device Interface
512
518
516
Tx
Rx
530
531
522
Rx
Tx
Table
Used#1=2
520
Device #1
Host Interface
Device Identifier Value = 2
Tx
Rx
524
546
514
ENUM CMD
Response Dev#2=7
550
551
542
Rx
Tx
Table
Used#1=2
Used#2=7
540
Device #2
Host Interface
Device Identifier Value = 7
Tx
Rx
544
Response Dev#2=7
546
Additional Devices

FIG. 5



610
Host Device
Enumerated Devices
Device #1=2
611
600
614
ENUM CMD 1
Memory Device Interface
612
630
631
633
622
Identifier Value Threshold = 2
635
Identifer Values
Device Identifier Value = 2
Offset Value 637
Device #1
Host Interface
604
662
673
670
671
Host Interface
Identifier Value Threshold = 2
675
Identifer Values
Device Identifier Value
Offset Value 677
Device #3
624
660
664
660
602
Response Dev#1=2
626
Host Interface
642
Identifier Value Threshold = 2
650
651
653
655
Identifer Values
Device Identifier Value
644
Offset Value 657
Device #2
640

FIG. 6

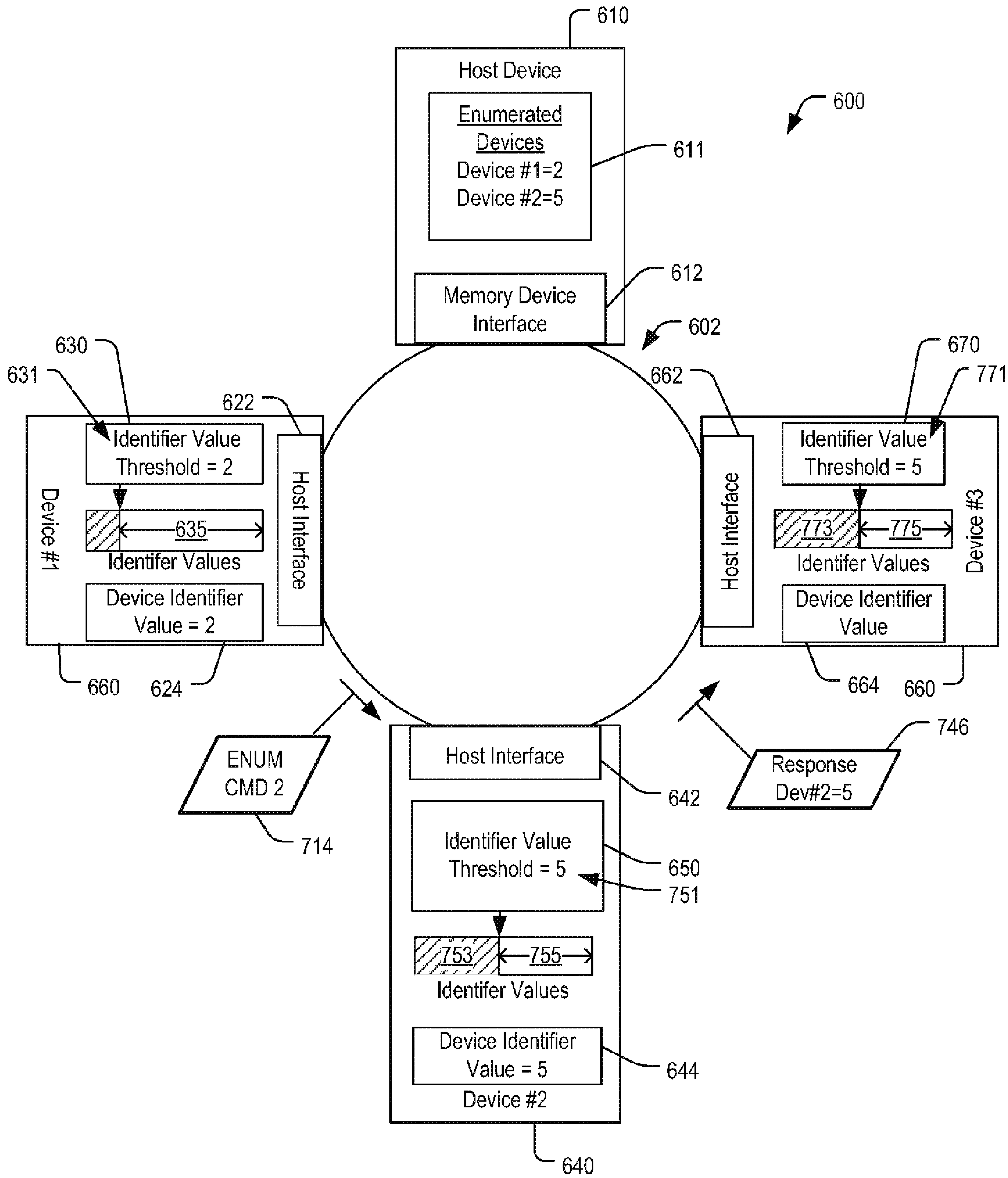
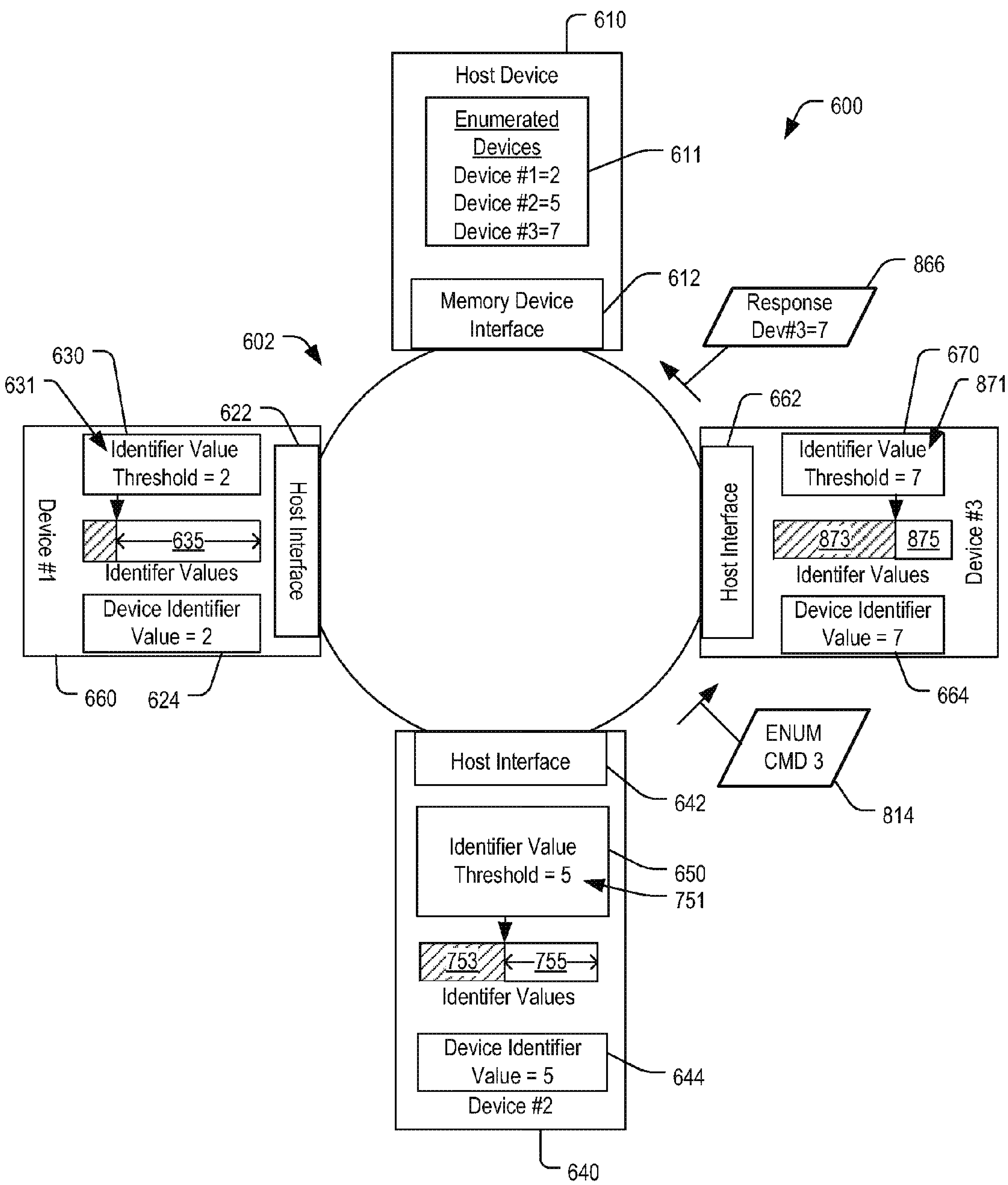
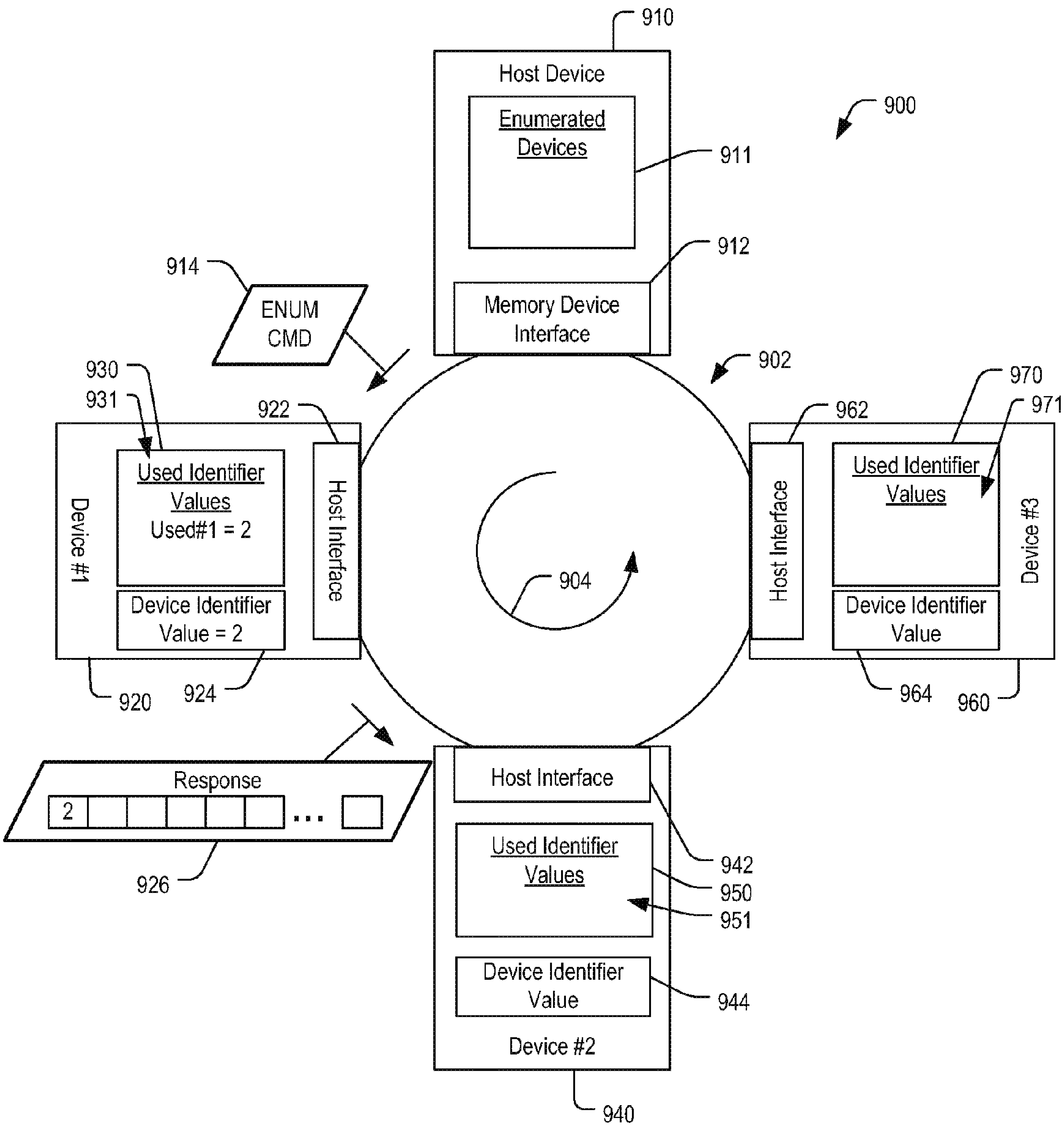

610
Host Device
Enumerated Devices
Device #1=2
Device #2=5
611
600
Memory Device Interface
612
602
630
631
622
Identifier Value Threshold = 2
635
Identifer Values
Device Identifier Value = 2
Host Interface
Device #1
660
624
670
771
662
Identifier Value Threshold = 5
773
775
Identifer Values
Device Identifier Value
Host Interface
Device #3
664
660
746
Response Dev#2=5
ENUM CMD 2
714
Host Interface
642
Identifier Value Threshold = 5
650
751
753
755
Identifer Values
Device Identifier Value = 5
644
Device #2
640

FIG. 7



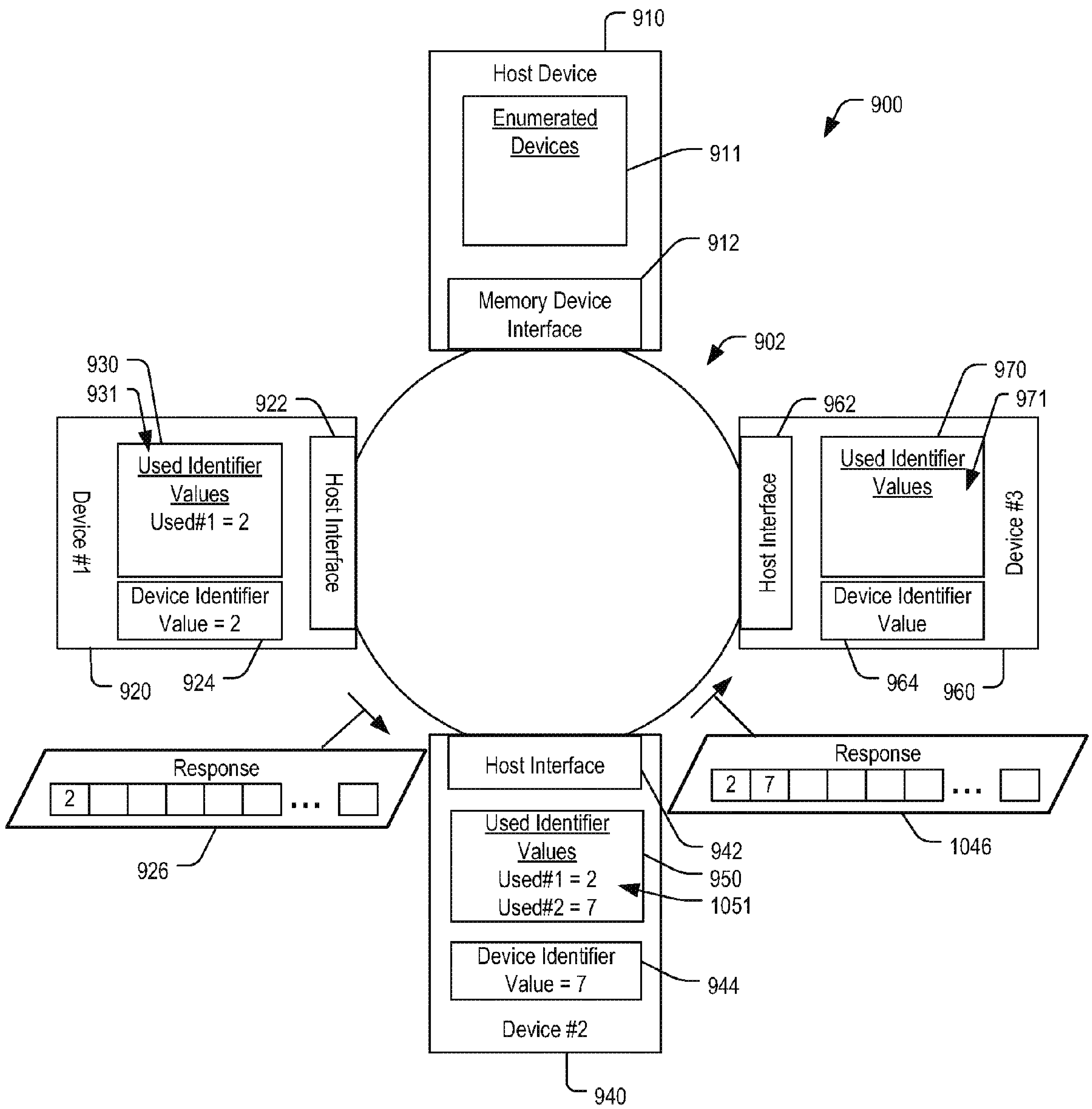
610
Host Device
Enumerated Devices
Device #1=2
Device #2=5
Device #3=7
611
600
612
Memory Device Interface
866
Response Dev#3=7
602
630
631
622
Identifier Value Threshold = 2
635
Identifer Values
Device Identifier Value = 2
Device #1
Host Interface
660
624
662
670
871
Identifier Value Threshold = 7
873
875
Identifer Values
Device Identifier Value = 7
Device #3
Host Interface
664
ENUM CMD 3
814
Host Interface
642
Identifier Value Threshold = 5
650
751
753
755
Identifer Values
Device Identifier Value = 5
644
Device #2
640

FIG. 8



910
Host Device
Enumerated Devices
911
912
Memory Device Interface
900
914
ENUM CMD
902
930
931
922
Used Identifier Values
Used#1 = 2
Device #1
Host Interface
Device Identifier Value = 2
920
924
904
962
970
971
Host Interface
Used Identifier Values
Device #3
Device Identifier Value
964
960
Response
2
...
926
Host Interface
942
Used Identifier Values
950
951
Device Identifier Value
944
Device #2
940

FIG. 9



910
Host Device
Enumerated Devices
911
912
Memory Device Interface
900
902
930
931
922
Used Identifier Values
Used#1 = 2
Device #1
Host Interface
Device Identifier Value = 2
920
924
970
971
962
Host Interface
Used Identifier Values
Device #3
Device Identifier Value
964
960
Response
2
926
Host Interface
Used Identifier Values
Used#1 = 2
Used#2 = 7
Device Identifier Value = 7
Device #2
942
950
1051
944
940
Response
2 7
1046

FIG. 10

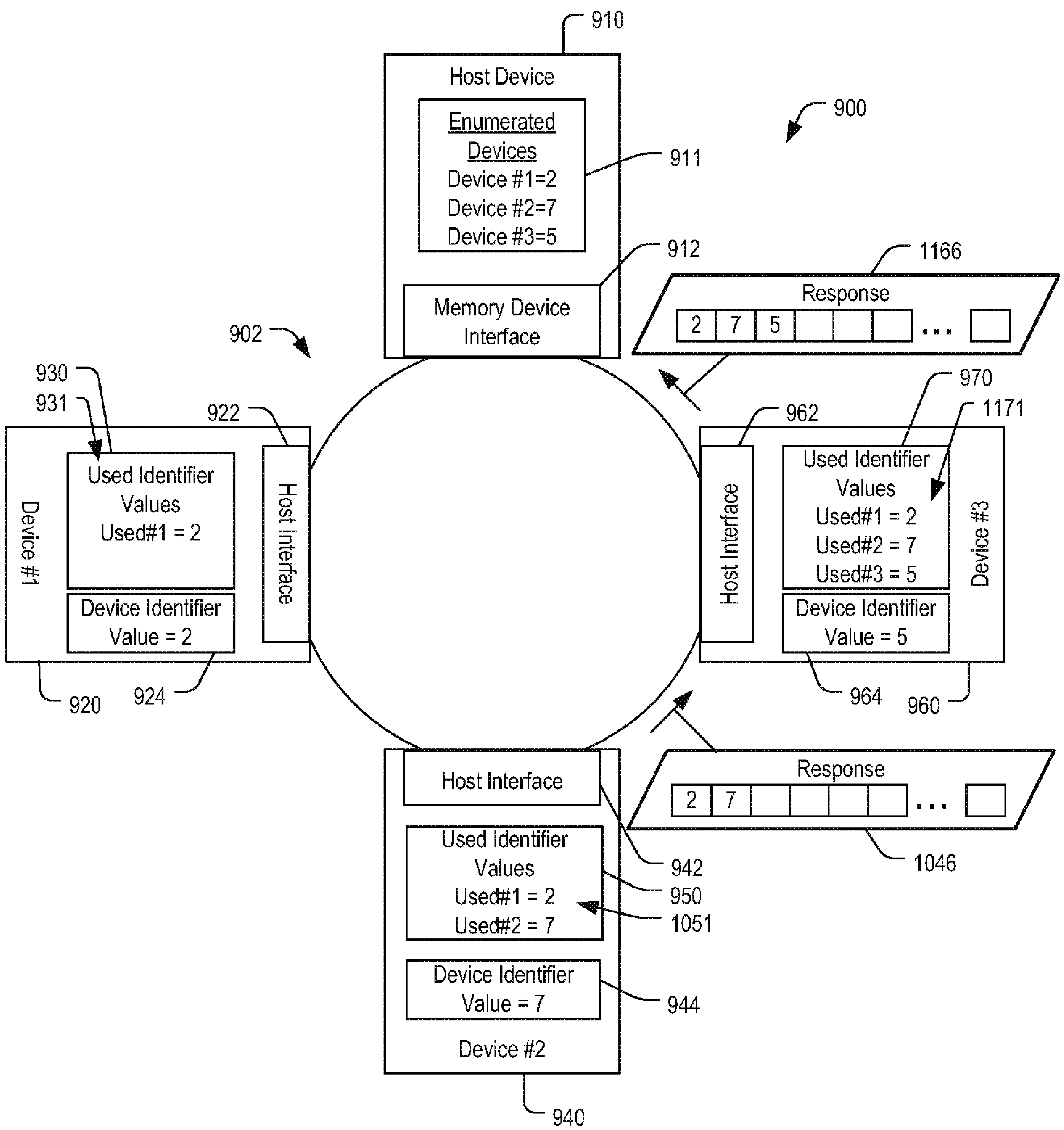

910
Host Device
Enumerated Devices
Device #1=2
Device #2=7
Device #3=5
900
911
912
Memory Device Interface
1166
Response
2 7 5 ...
902
930
931
922
Used Identifier Values
Used#1 = 2
Device #1
Host Interface
Device Identifier Value = 2
920
924
962
970
1171
Host Interface
Used Identifier Values
Used#1 = 2
Used#2 = 7
Used#3 = 5
Device #3
Device Identifier Value = 5
964
960
Response
2 7 ...
Host Interface
Used Identifier Values
Used#1 = 2
Used#2 = 7
942
950
1051
1046
Device Identifier Value = 7
944
Device #2
940

FIG. 11

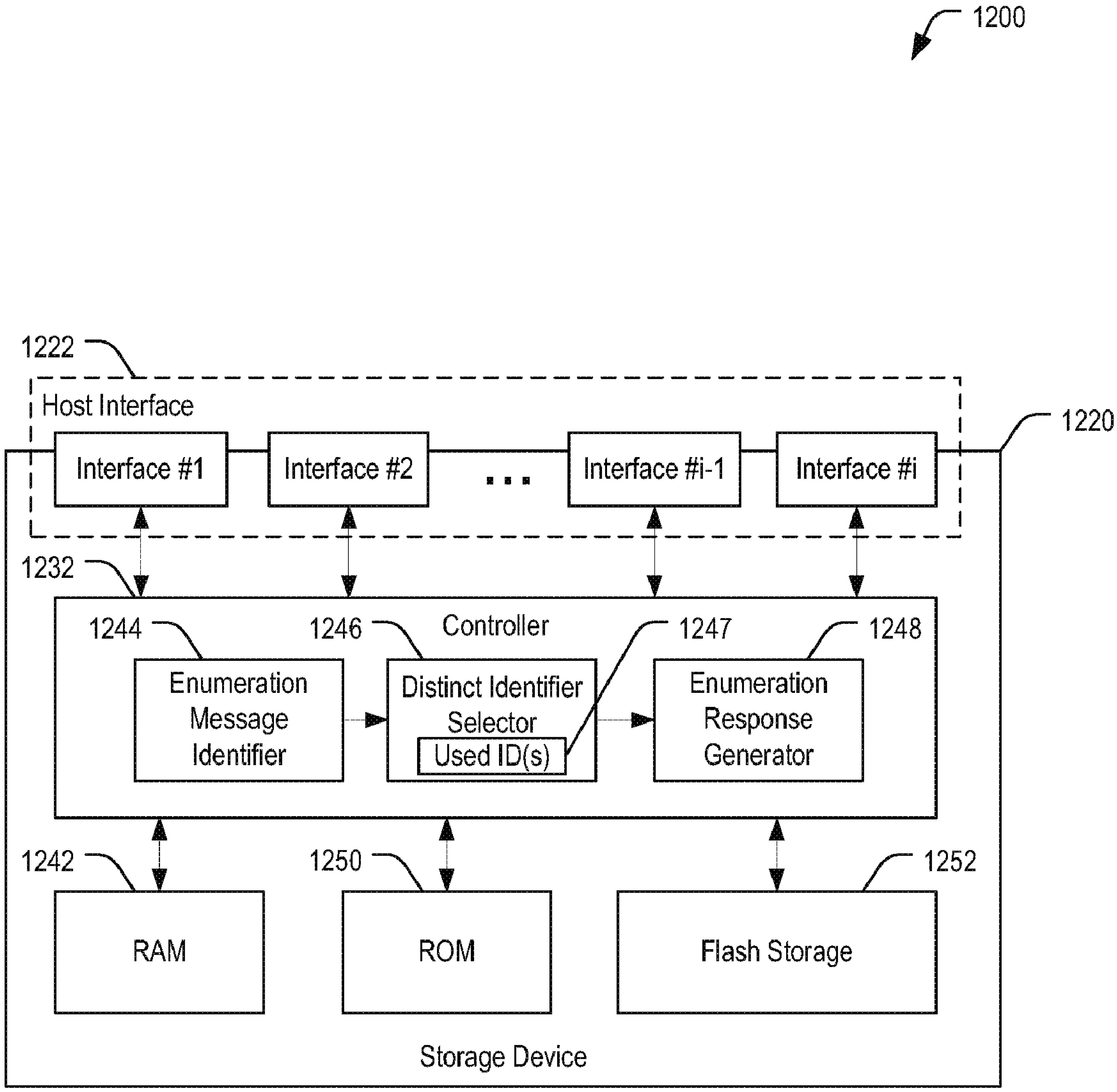

1200
1222
Host Interface
1220
Interface #1
Interface #2
...
Interface #i-1
Interface #i
1232
1244
1246
Controller
1247
1248
Enumeration Message Identifier
Distinct Identifier Selector
Used ID(s)
Enumeration Response Generator
1242
1250
1252
RAM
ROM
Flash Storage
Storage Device

FIG. 12

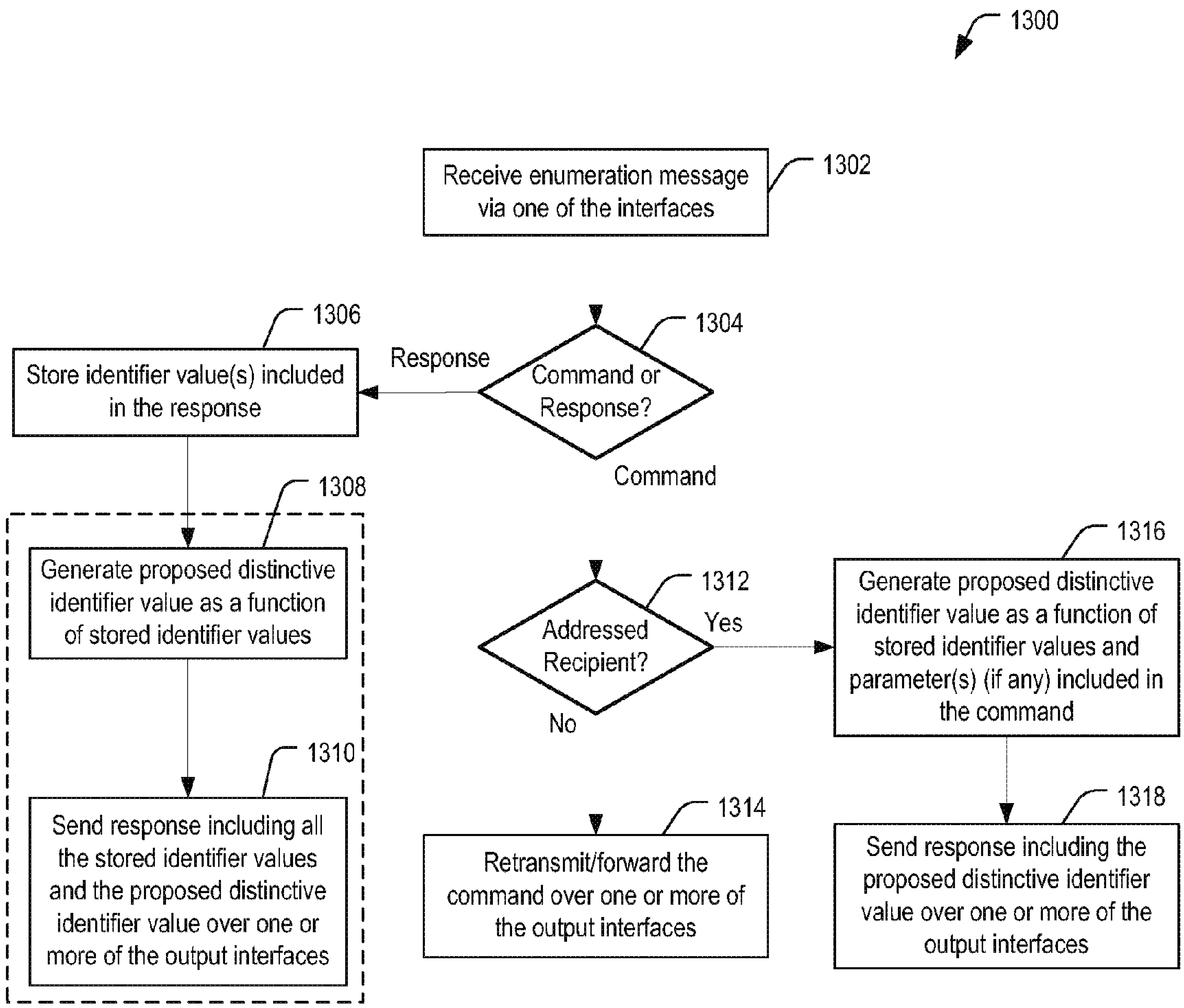

1300
Receive enumeration message via one of the interfaces
1302
1304
Command or Response?
Response
Command
1306
Store identifier value(s) included in the response
1308
Generate proposed distinctive identifier value as a function of stored identifier values
1310
Send response including all the stored identifier values and the proposed distinctive identifier value over one or more of the output interfaces
1312
Addressed Recipient?
Yes
No
1314
Retransmit/forward the command over one or more of the output interfaces
1316
Generate proposed distinctive identifier value as a function of stored identifier values and parameter(s) (if any) included in the command
1318
Send response including the proposed distinctive identifier value over one or more of the output interfaces

FIG. 13

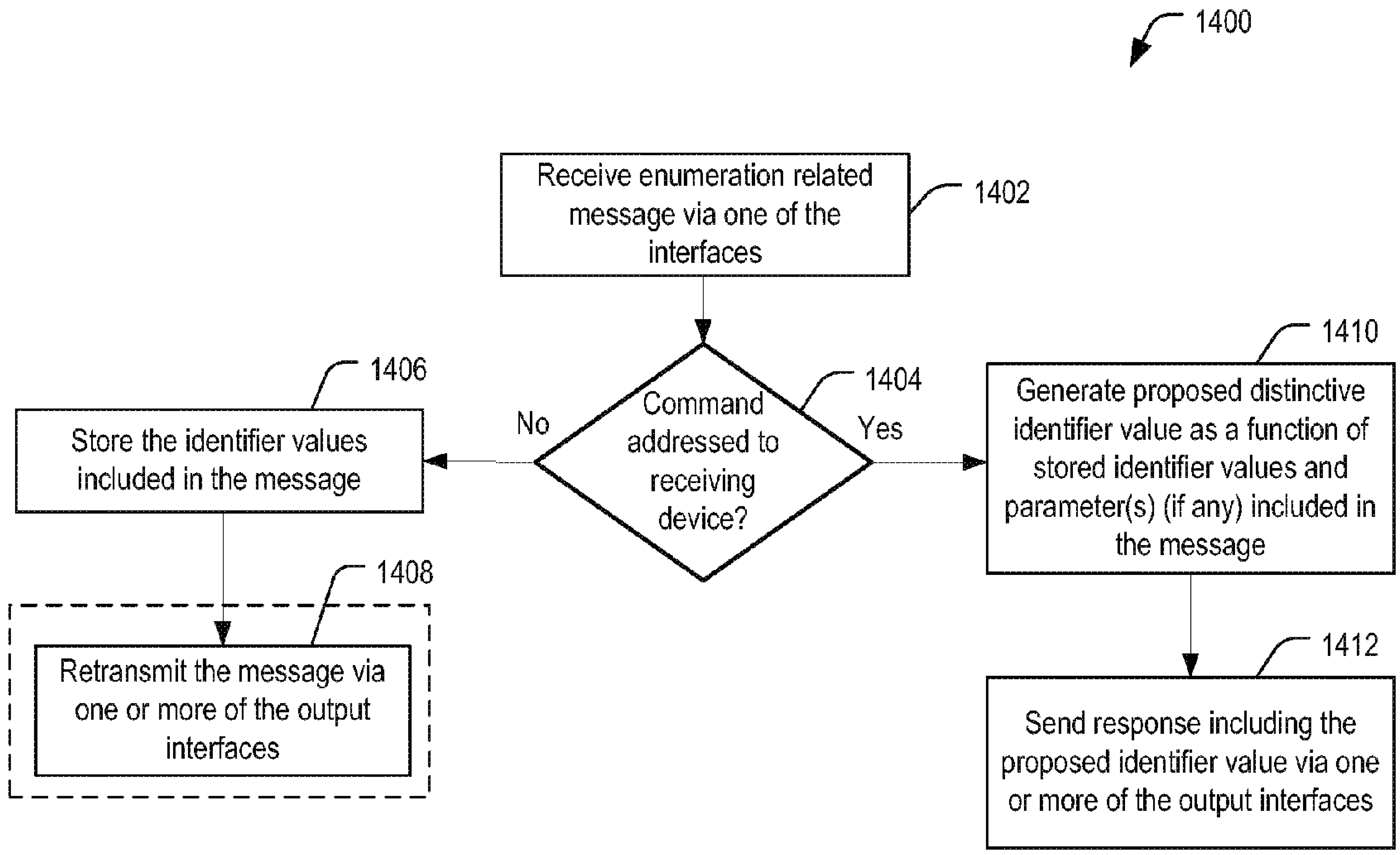

1400
Receive enumeration related message via one of the interfaces
1402
Command addressed to receiving device?
1404
No
Yes
Store the identifier values included in the message
1406
Retransmit the message via one or more of the output interfaces
1408
Generate proposed distinctive identifier value as a function of stored identifier values and parameter(s) (if any) included in the message
1410
Send response including the proposed identifier value via one or more of the output interfaces
1412

FIG. 14

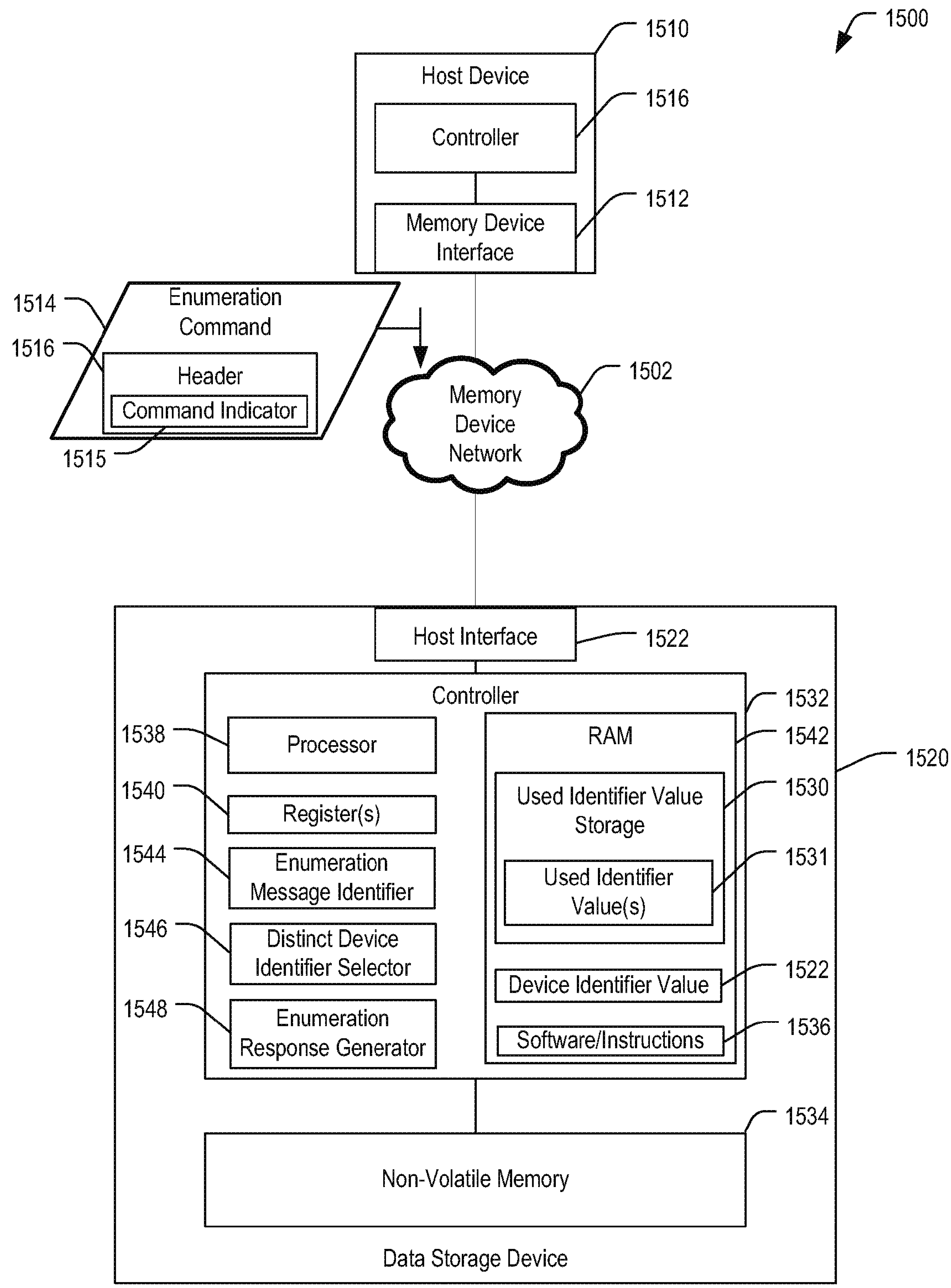

1500
1510
Host Device
Controller
1516
1512
Memory Device Interface
1514
Enumeration Command
1516
Header
Command Indicator
1515
1502
Memory Device Network
Host Interface
1522
Controller
1532
1538
Processor
RAM
1542
1520
1540
Register(s)
Used Identifier Value Storage
1530
1544
Enumeration Message Identifier
Used Identifier Value(s)
1531
1546
Distinct Device Identifier Selector
1548
Enumeration Response Generator
Device Identifier Value
1522
Software/Instructions
1536
1534
Non-Volatile Memory
Data Storage Device

FIG. 15

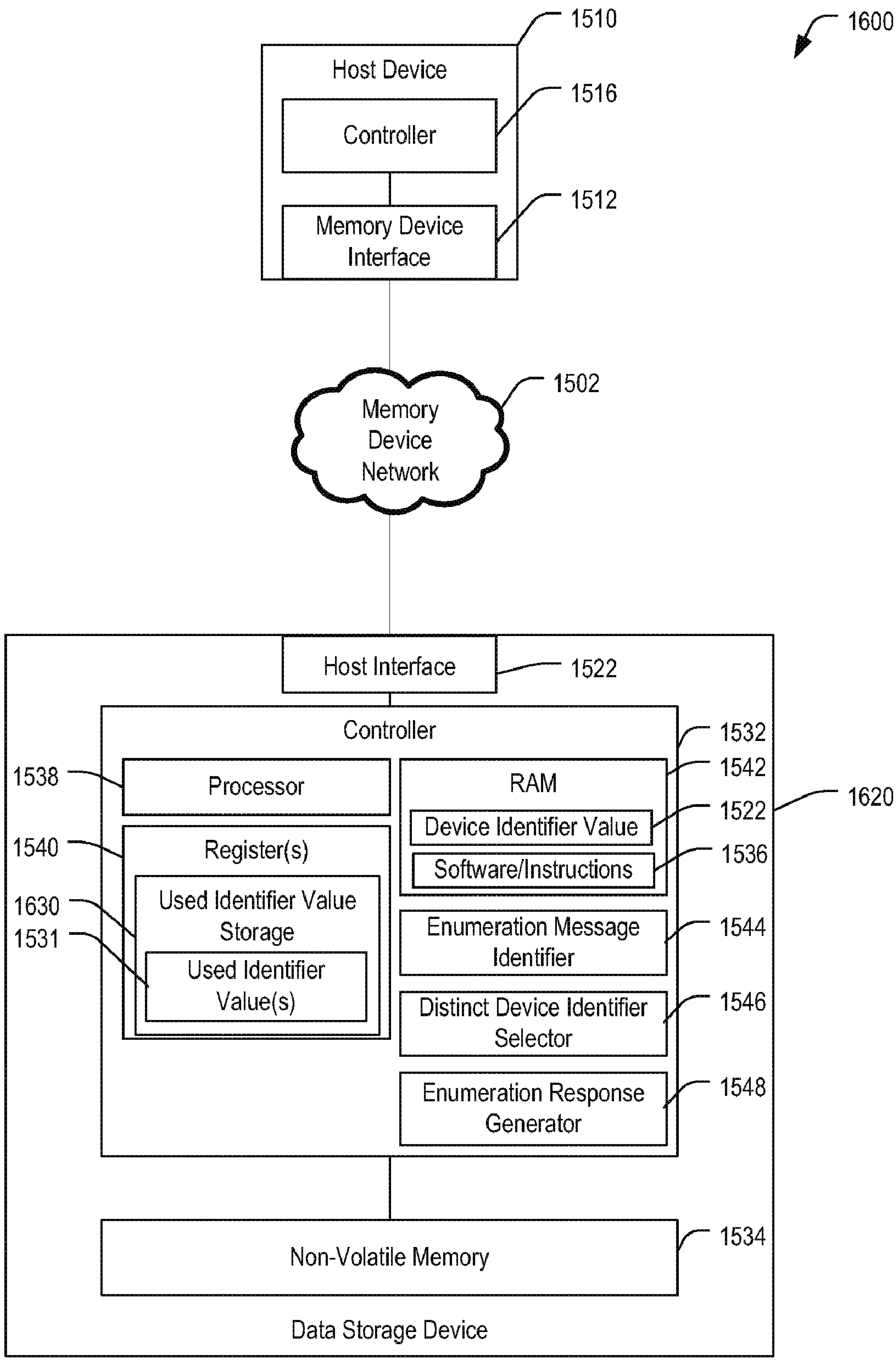

1600
1510
Host Device
1516
Controller
1512
Memory Device Interface
1502
Memory Device Network
Host Interface
1522
Controller
1532
1538
Processor
RAM
1542
Device Identifier Value
1522
1620
Software/Instructions
1536
1540
Register(s)
1630
Used Identifier Value Storage
1531
Used Identifier Value(s)
Enumeration Message Identifier
1544
Distinct Device Identifier Selector
1546
Enumeration Response Generator
1548
Non-Volatile Memory
1534
Data Storage Device

FIG. 16

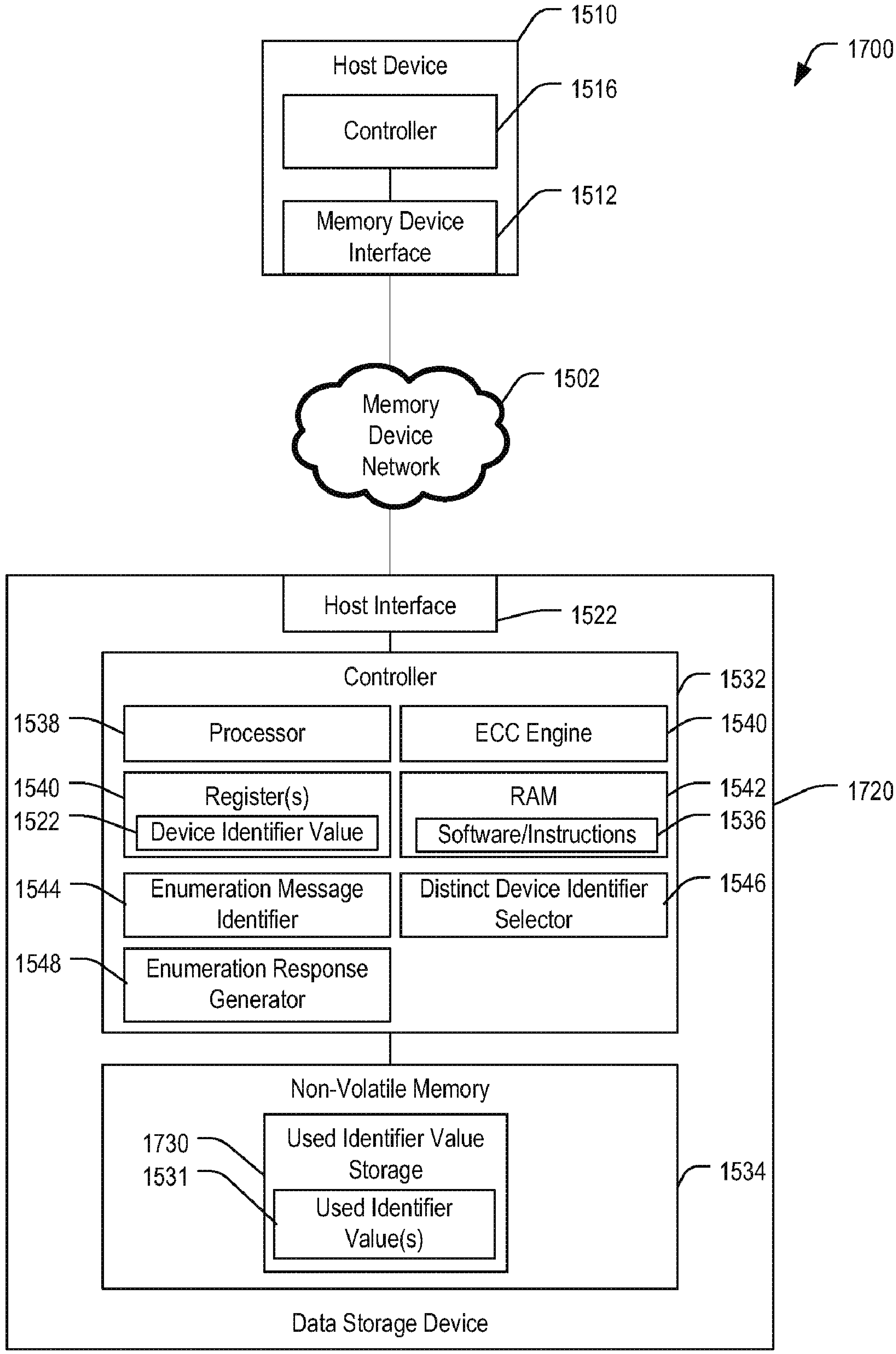

1700
1510
Host Device
Controller
1516
Memory Device Interface
1512
Memory Device Network
1502
Host Interface
1522
Controller
1532
1538
Processor
ECC Engine
1540
1540
Register(s)
1522
Device Identifier Value
RAM
1542
Software/Instructions
1536
1720
1544
Enumeration Message Identifier
Distinct Device Identifier Selector
1546
1548
Enumeration Response Generator
Non-Volatile Memory
1730
Used Identifier Value Storage
1531
Used Identifier Value(s)
1534
Data Storage Device

FIG. 17

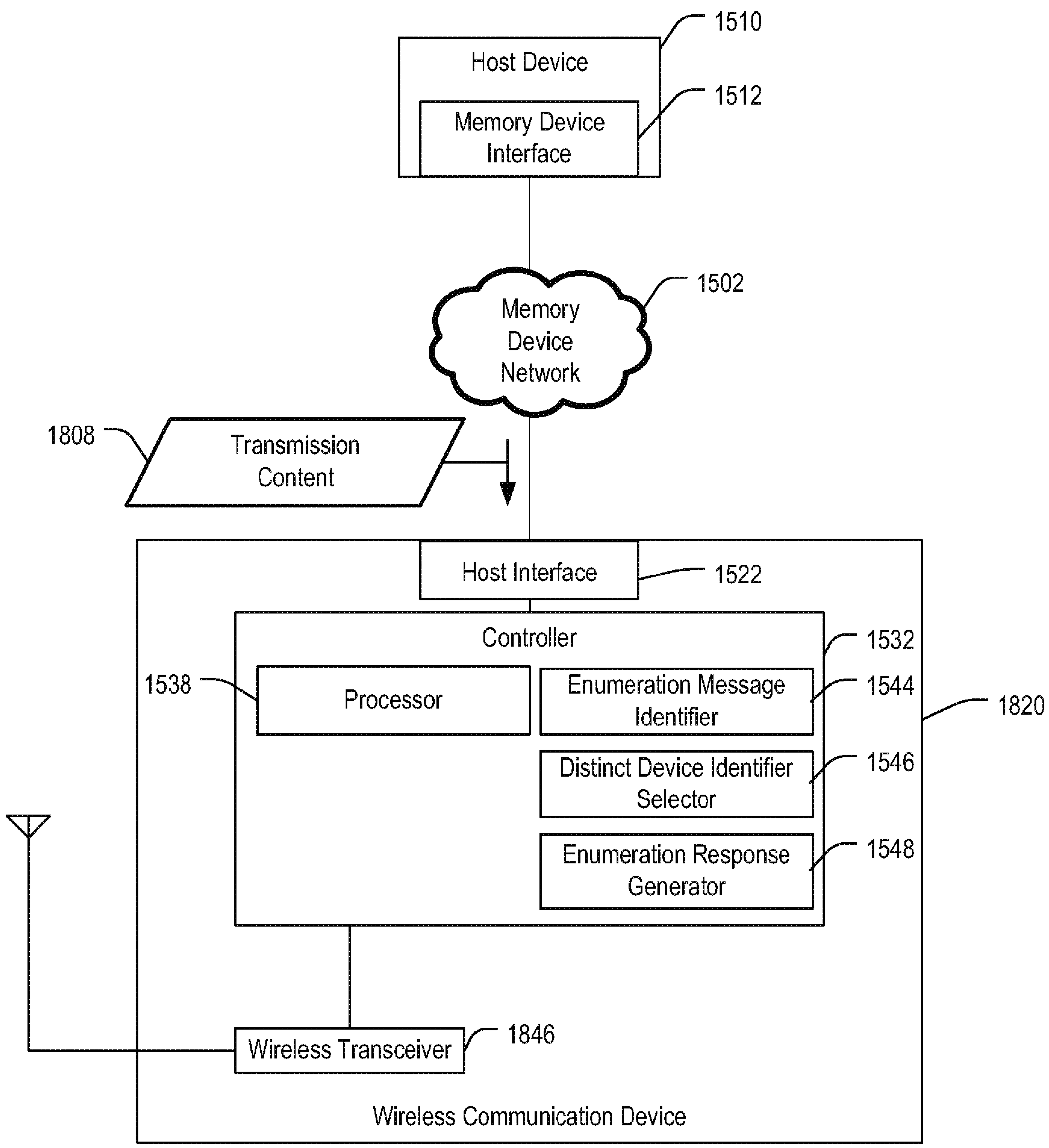

1510
Host Device
1512
Memory Device Interface
1502
Memory Device Network
1808
Transmission Content
Host Interface
1522
Controller
1532
1538
Processor
Enumeration Message Identifier
1544
1820
Distinct Device Identifier Selector
1546
Enumeration Response Generator
1548
Wireless Transceiver
1846
Wireless Communication Device

FIG. 18

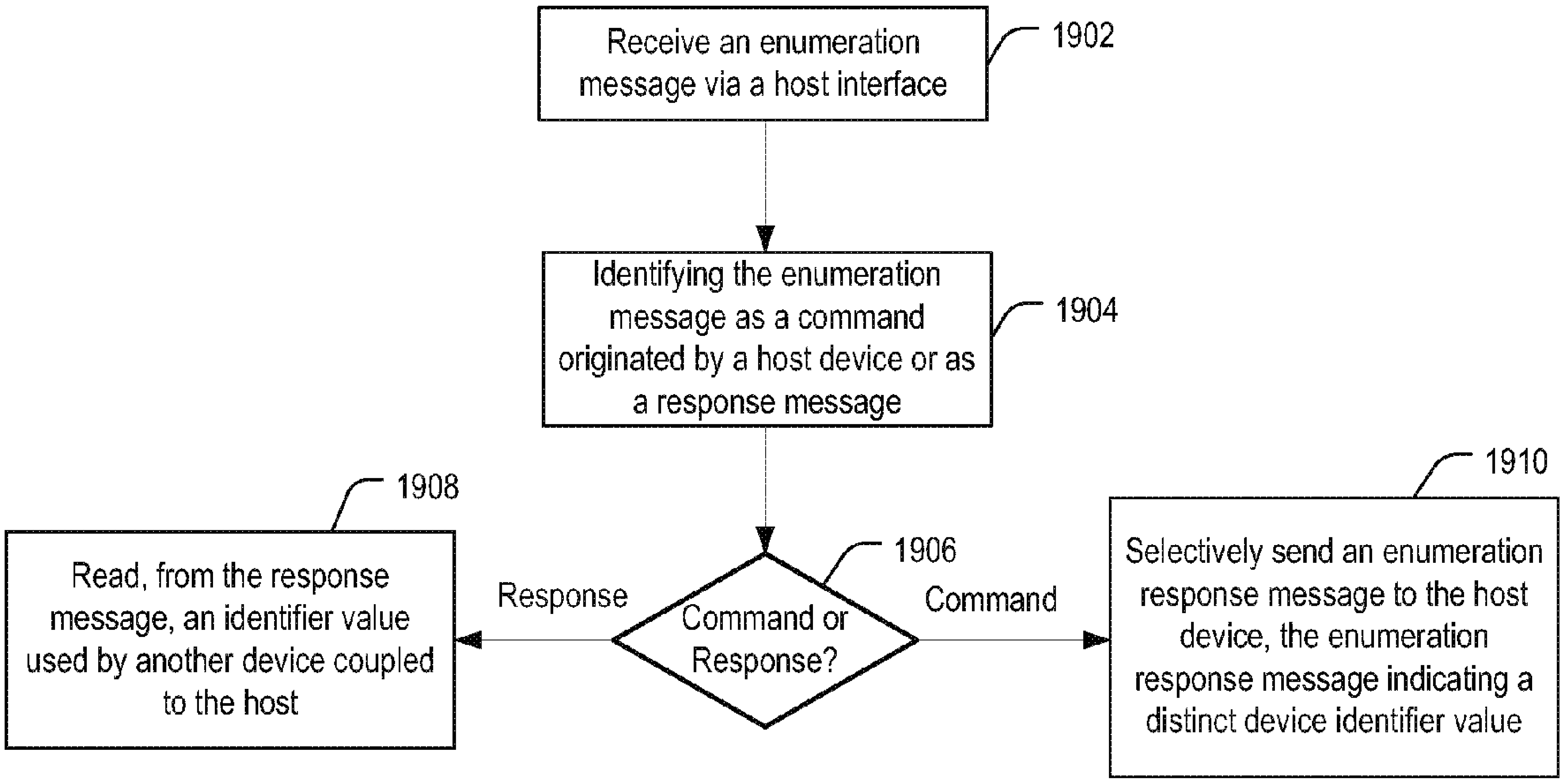

Receive an enumeration message via a host interface
1902
Identifying the enumeration message as a command originated by a host device or as a response message
1904
Command or Response?
1906
Response
Command
Read, from the response message, an identifier value used by another device coupled to the host
1908
Selectively send an enumeration response message to the host device, the enumeration response message indicating a distinct device identifier value
1910

FIG. 19

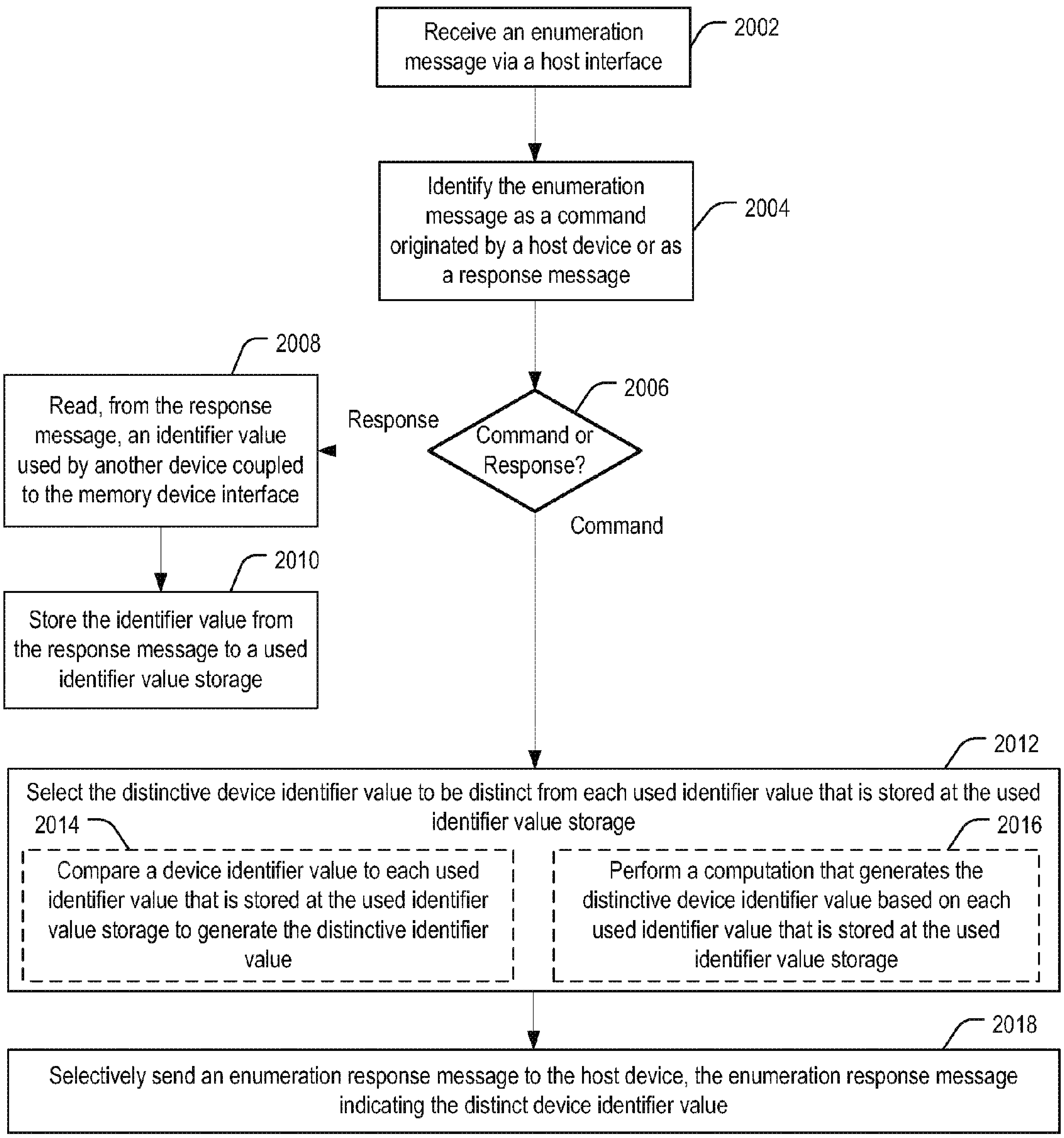

Receive an enumeration message via a host interface
2002
Identify the enumeration message as a command originated by a host device or as a response message
2004
2006
Command or Response?
Response
Command
2008
Read, from the response message, an identifier value used by another device coupled to the memory device interface
2010
Store the identifier value from the response message to a used identifier value storage
2012
Select the distinctive device identifier value to be distinct from each used identifier value that is stored at the used identifier value storage
2014
Compare a device identifier value to each used identifier value that is stored at the used identifier value storage to generate the distinctive identifier value
2016
Perform a computation that generates the distinctive device identifier value based on each used identifier value that is stored at the used identifier value storage
2018
Selectively send an enumeration response message to the host device, the enumeration response message indicating the distinct device identifier value

FIG. 20

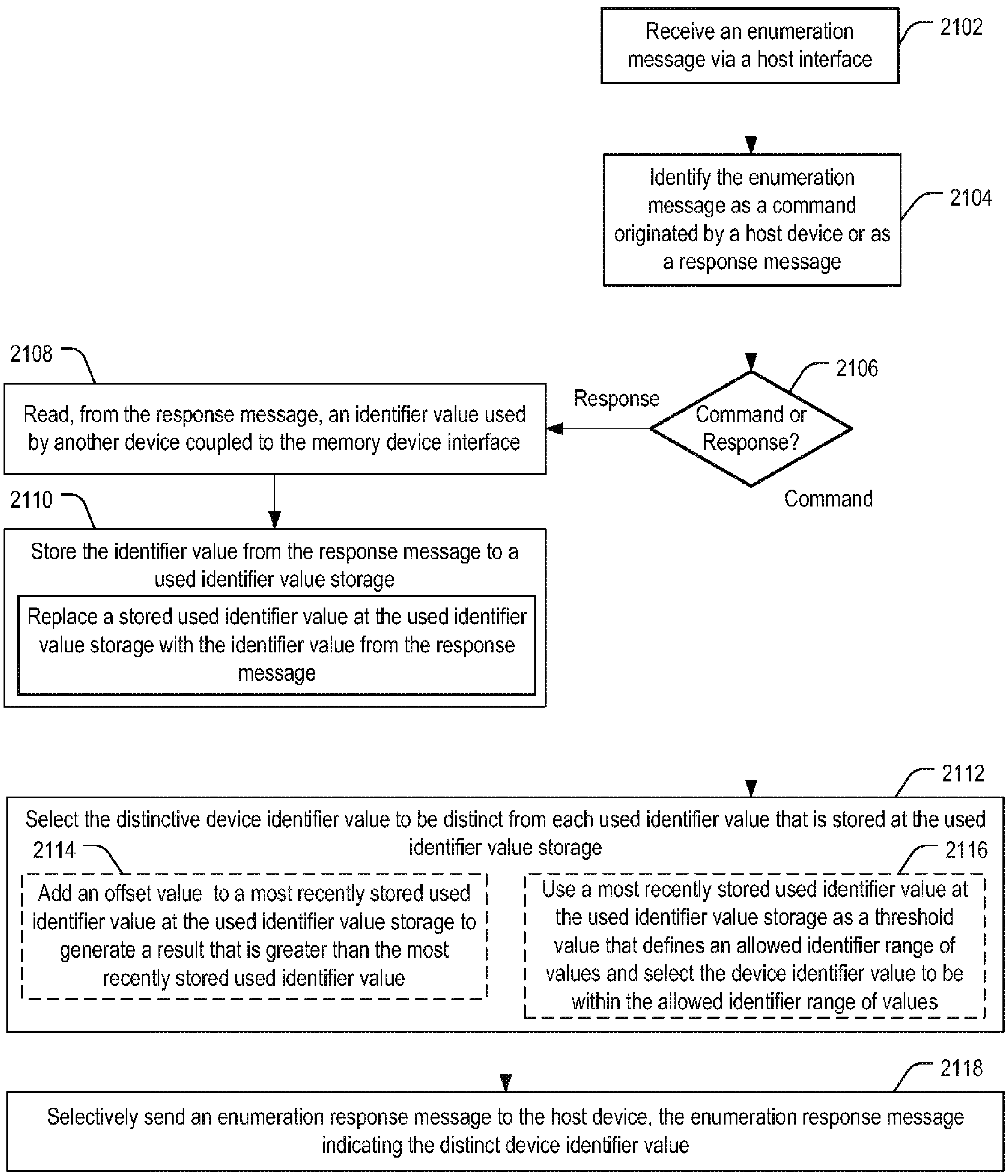

Receive an enumeration message via a host interface
2102
Identify the enumeration message as a command originated by a host device or as a response message
2104
Command or Response?
2106
Response
Command
2108
Read, from the response message, an identifier value used by another device coupled to the memory device interface
2110
Store the identifier value from the response message to a used identifier value storage
Replace a stored used identifier value at the used identifier value storage with the identifier value from the response message
2112
Select the distinctive device identifier value to be distinct from each used identifier value that is stored at the used identifier value storage
2114
Add an offset value to a most recently stored used identifier value at the used identifier value storage to generate a result that is greater than the most recently stored used identifier value
2116
Use a most recently stored used identifier value at the used identifier value storage as a threshold value that defines an allowed identifier range of values and select the device identifier value to be within the allowed identifier range of values
2118
Selectively send an enumeration response message to the host device, the enumeration response message indicating the distinct device identifier value

FIG. 21

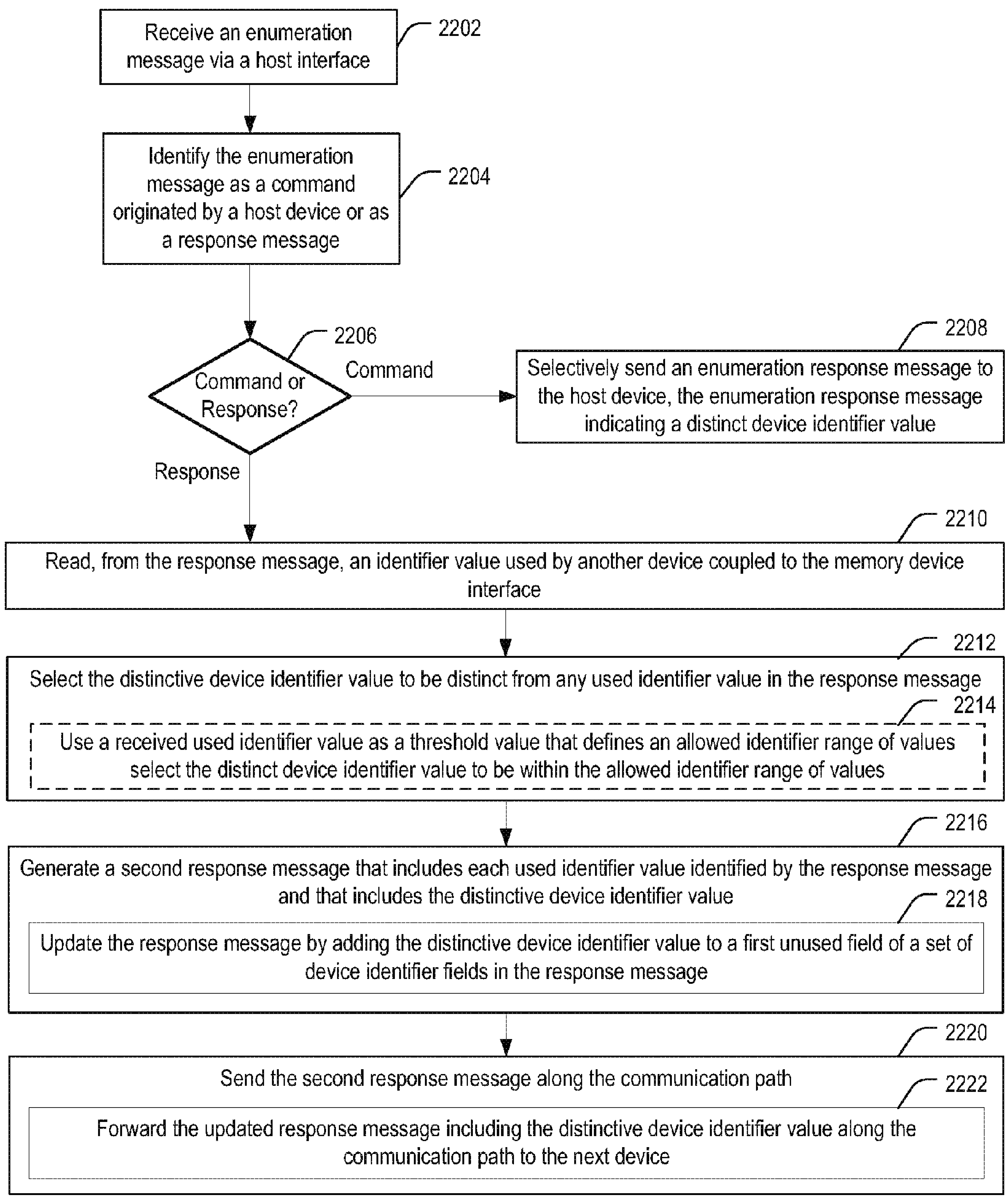

Receive an enumeration message via a host interface
2202
Identify the enumeration message as a command originated by a host device or as a response message
2204
2206
Command or Response?
Command
2208
Selectively send an enumeration response message to the host device, the enumeration response message indicating a distinct device identifier value
Response
2210
Read, from the response message, an identifier value used by another device coupled to the memory device interface
2212
Select the distinctive device identifier value to be distinct from any used identifier value in the response message
2214
Use a received used identifier value as a threshold value that defines an allowed identifier range of values select the distinct device identifier value to be within the allowed identifier range of values
2216
Generate a second response message that includes each used identifier value identified by the response message and that includes the distinctive device identifier value
2218
Update the response message by adding the distinctive device identifier value to a first unused field of a set of device identifier fields in the response message
2220
Send the second response message along the communication path
2222
Forward the updated response message including the distinctive device identifier value along the communication path to the next device

FIG. 22

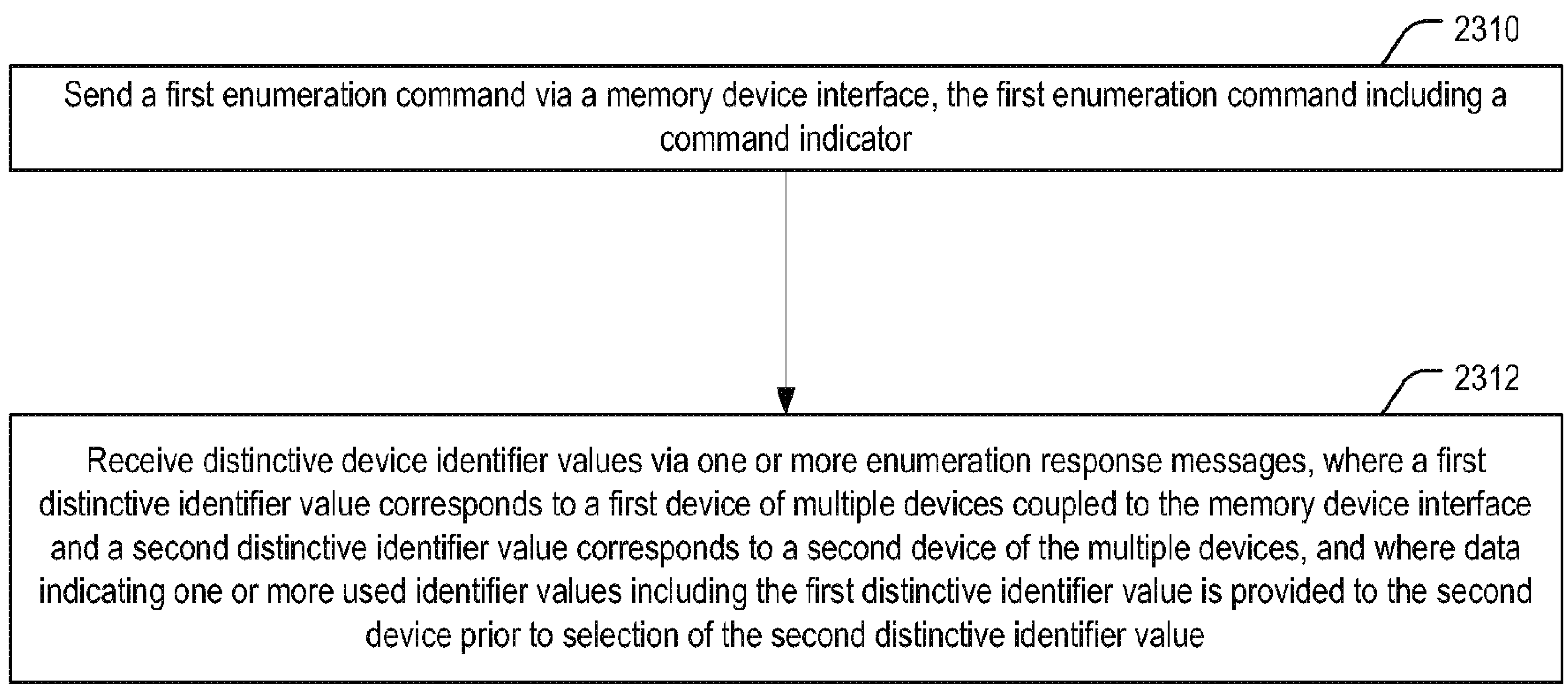

2310
Send a first enumeration command via a memory device interface, the first enumeration command including a command indicator
2312
Receive distinctive device identifier values via one or more enumeration response messages, where a first distinctive identifier value corresponds to a first device of multiple devices coupled to the memory device interface and a second distinctive identifier value corresponds to a second device of the multiple devices, and where data indicating one or more used identifier values including the first distinctive identifier value is provided to the second device prior to selection of the second distinctive identifier value

FIG. 23

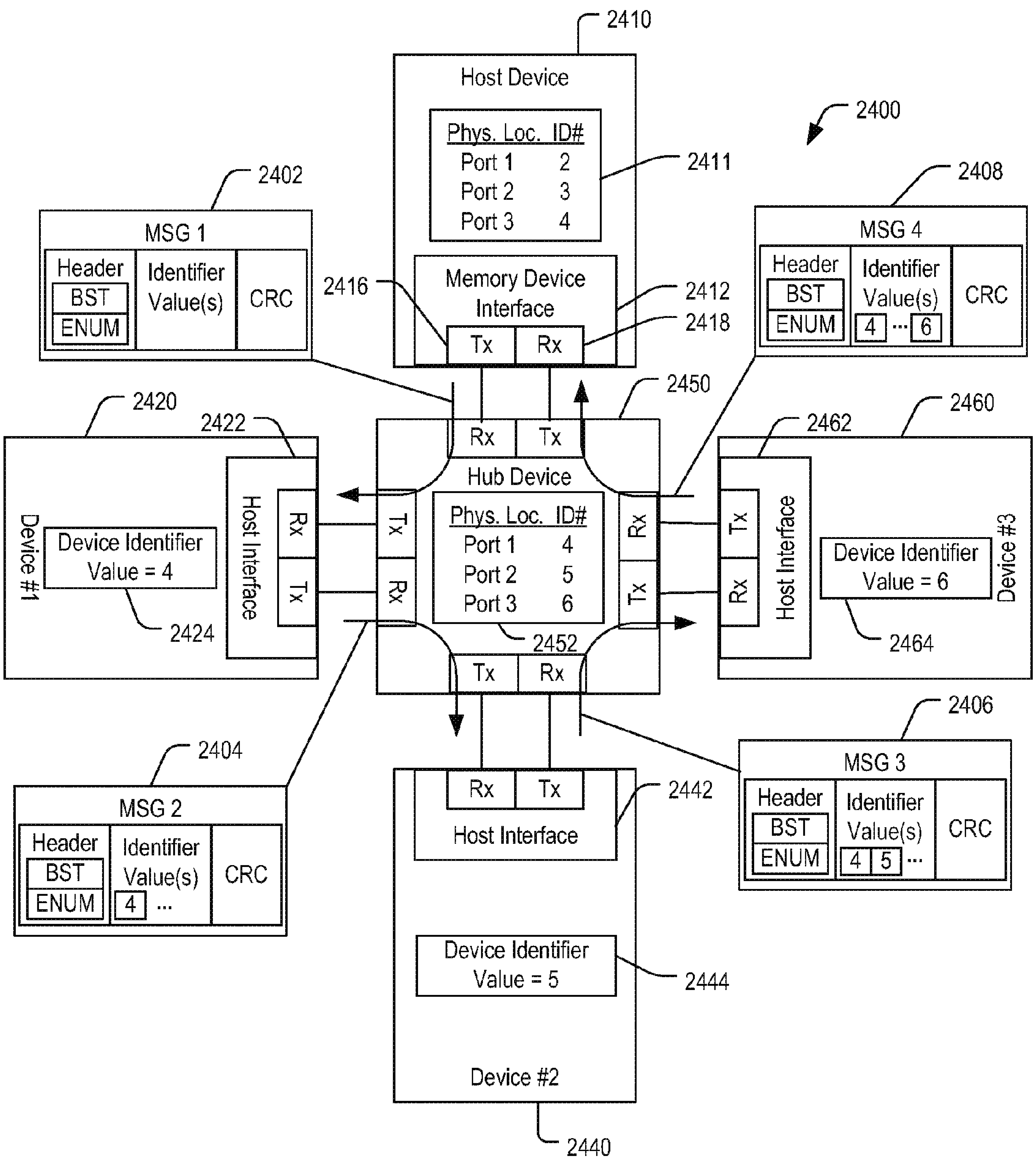

2410
Host Device
Phys. Loc. ID#
Port 1 2
Port 2 3
Port 3 4
2411
2400
2402
MSG 1
Header
BST
ENUM
Identifier Value(s)
CRC
2416
Memory Device Interface
Tx
Rx
2412
2418
2408
MSG 4
Header
BST
ENUM
Identifier Value(s)
4 ··· 6
CRC
2450
2420
2422
Device #1
Device Identifier Value = 4
Host Interface
Rx
Tx
2424
Hub Device
Phys. Loc. ID#
Port 1 4
Port 2 5
Port 3 6
2452
2462
2460
Host Interface
Device Identifier Value = 6
Device #3
2464
2404
MSG 2
Header
BST
ENUM
Identifier Value(s)
4 ...
CRC
2406
MSG 3
Header
BST
ENUM
Identifier Value(s)
4 5 ···
CRC
2442
Host Interface
Device Identifier Value = 5
2444
Device #2
2440

FIG. 24

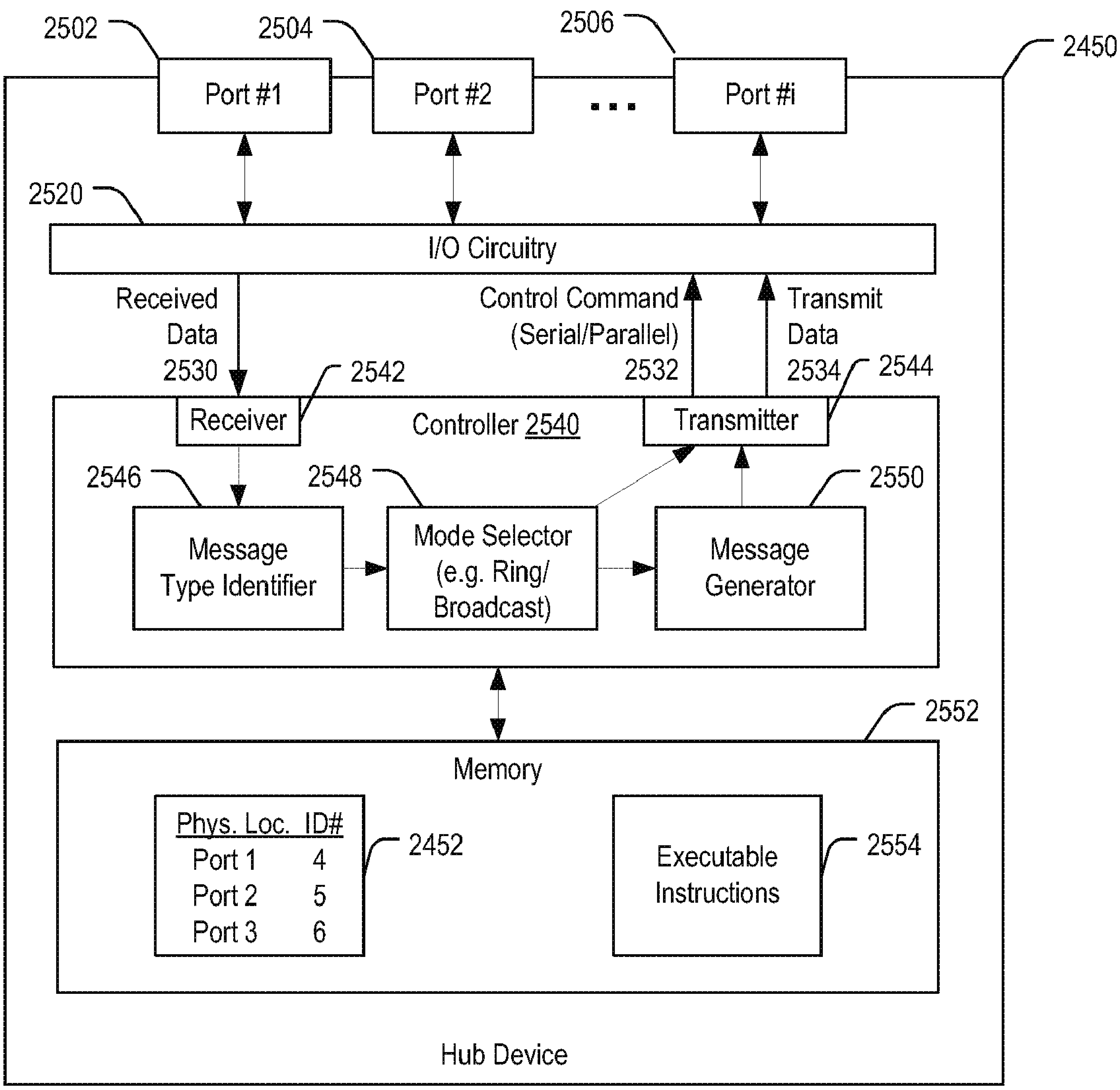

2502
2504
2506
2450
Port #1
Port #2
Port #i
2520
I/O Circuitry
Received Data 2530
Control Command (Serial/Parallel) 2532
Transmit Data 2534
2542
2544
Receiver
Controller 2540
Transmitter
2546
2548
2550
Message Type Identifier
Mode Selector (e.g. Ring/ Broadcast)
Message Generator
2552
Memory
Phys. Loc. ID#
Port 1 4
Port 2 5
Port 3 6
2452
Executable Instructions
2554
Hub Device

FIG. 25

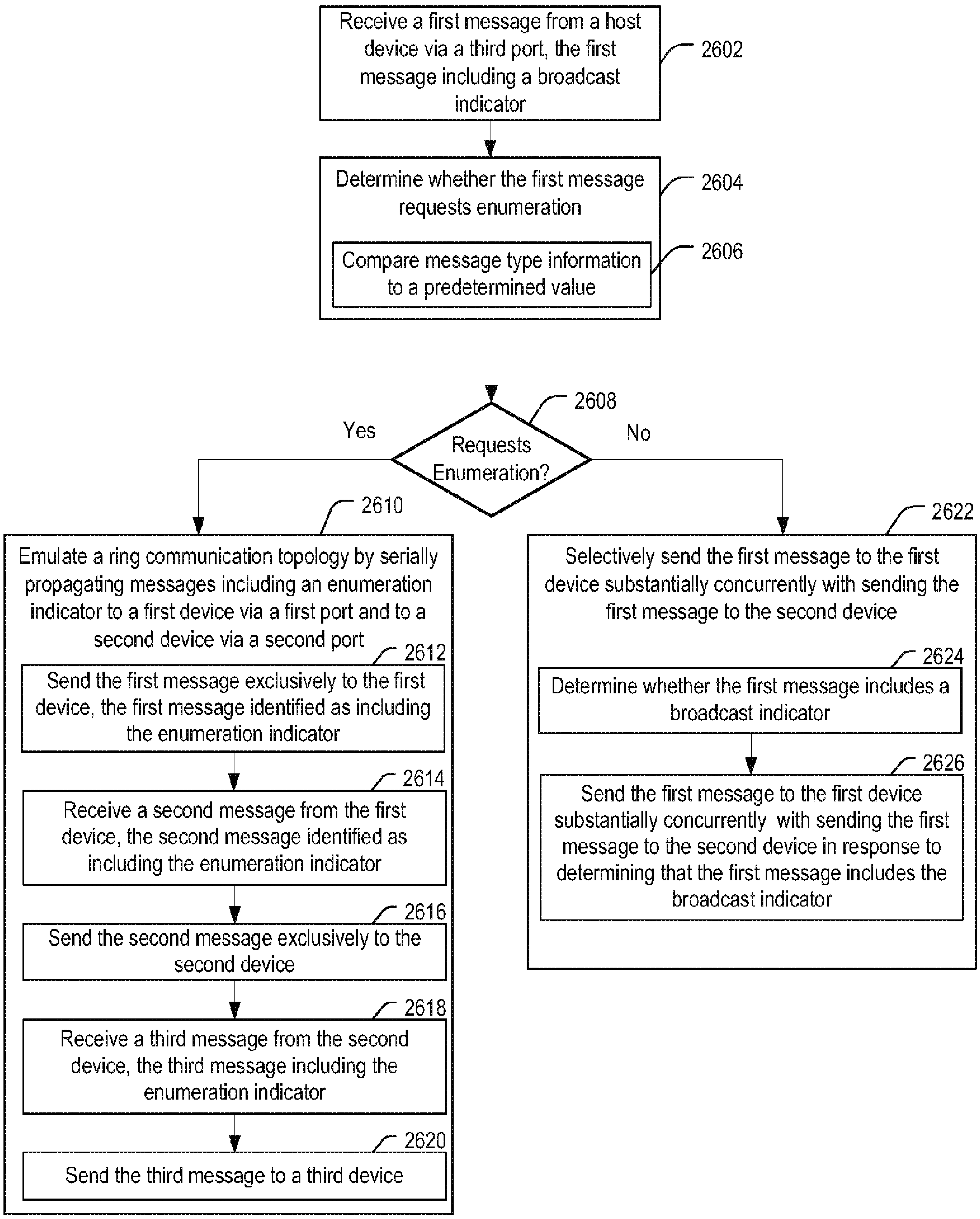

Receive a first message from a host device via a third port, the first message including a broadcast indicator
2602
Determine whether the first message requests enumeration
2604
Compare message type information to a predetermined value
2606
2608
Requests Enumeration?
Yes
No
2610
Emulate a ring communication topology by serially propagating messages including an enumeration indicator to a first device via a first port and to a second device via a second port
2612
Send the first message exclusively to the first device, the first message identified as including the enumeration indicator
2614
Receive a second message from the first device, the second message identified as including the enumeration indicator
2616
Send the second message exclusively to the second device
2618
Receive a third message from the second device, the third message including the enumeration indicator
2620
Send the third message to a third device
2622
Selectively send the first message to the first device substantially concurrently with sending the first message to the second device
2624
Determine whether the first message includes a broadcast indicator
2626
Send the first message to the first device substantially concurrently with sending the first message to the second device in response to determining that the first message includes the broadcast indicator

FIG. 26

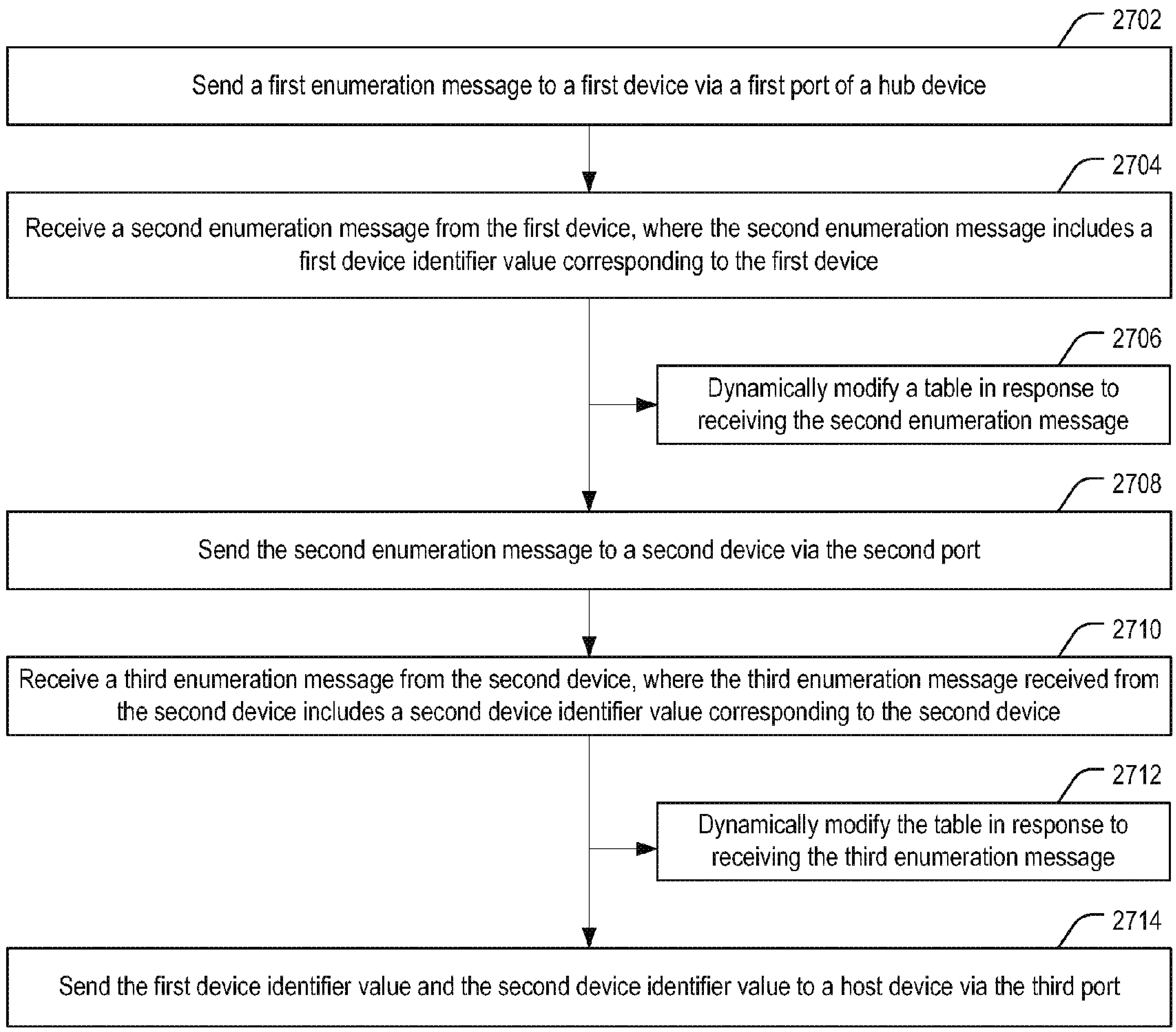

2702
Send a first enumeration message to a first device via a first port of a hub device
2704
Receive a second enumeration message from the first device, where the second enumeration message includes a first device identifier value corresponding to the first device
2706
Dynamically modify a table in response to receiving the second enumeration message
2708
Send the second enumeration message to a second device via the second port
2710
Receive a third enumeration message from the second device, where the third enumeration message received from the second device includes a second device identifier value corresponding to the second device
2712
Dynamically modify the table in response to receiving the third enumeration message
2714
Send the first device identifier value and the second device identifier value to a host device via the third port

FIG. 27

DEVICE IDENTIFIER SELECTION

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of and claims priority under 35 U.S.C. §120 to commonly-owned, co-pending U.S. patent application Ser. No. 12/509,832, filed Jul. 27, 2009, entitled "DEVICE IDENTIFIER SELECTION," which application is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

The present disclosure is generally related to selecting a device identifier.

BACKGROUND

Non-volatile memory devices, such as universal serial bus (USB) flash memory devices and removable memory cards, have allowed for increased portability of data and software applications. Host devices, such as cameras or mobile phones, may include a memory device interface that enables the host device to access one or more memory devices, such a USB flash memory device or a removable memory card. A host device may perform an enumeration process to determine identifiers for each device coupled to the memory device interface.

A conventional enumeration process may include receiving a first identifier from a first memory device, receiving a second identifier from a second memory device, comparing the second identifier to the first identifier, and requesting a new identifier from the second memory device if the first and second identifiers are the same. Often, however, devices are configured by a device manufacturer to select a common initial identifier value and to increment a previously selected identifier value by a pre-set amount each time the host requests a new identifier from the memory device. To illustrate, each device may initially select the identifier value "1," followed by "2," "3," and so on until an unused identifier value is found. In this case, a fifth enumerated device would select four unusable identifier values prior to selecting an identifier value that does not duplicate identifiers of the previously enumerated devices. Enumerating two devices may require three sequential identifier transmissions from the device to the host, enumerating three devices may require six identifier transmissions, and enumerating five devices may require fifteen identifier transmissions. Hence, there is a need for a more efficient method of selecting a device identifier at a memory device interface.

SUMMARY

A hub device is configured to emulate a ring communication topology to enable distinctive device identifier value selection by devices coupled to the hub device during an enumeration operation. The hub device may be configured to operate in an emulated ring topology mode during an enumeration operation. Emulating the ring topology may include serially propagating one or more enumeration messages from device to device to enable each subsequent device to determine an identifier value that is distinct from identifier values indicated as used by other devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a first particular embodiment of a system to select a device identifier value;

FIG. **2** is a block diagram of a second particular embodiment of a system to select a device identifier value showing a first device response to a first enumeration command in a ring topology;

FIG. **3** is a block diagram of the system of FIG. **2** showing a second device response to a second enumeration command;

FIG. **4** is a block diagram of the system of FIG. **2** showing a third device response to a third enumeration command;

FIG. **5** is a block diagram of a third particular embodiment of a system to select a device identifier value illustrating a first device response to an enumeration command in a linear daisy chain topology;

FIG. **6** is a block diagram of a fourth particular embodiment of a system to select a device identifier value illustrating a first device response to a first enumeration command in a ring topology;

FIG. **7** is a block diagram of the system of FIG. **6** showing a second device response to a second enumeration command;

FIG. **8** is a block diagram of the system of FIG. **6** showing a third device response to a third enumeration command;

FIG. **9** is a block diagram of a fifth particular embodiment of a system to select a device identifier value illustrating a response to an enumeration command by a first device in a ring topology;

FIG. **10** is a block diagram of the system of FIG. **9** illustrating a modification of the response by a second device;

FIG. **11** is a block diagram of the system of FIG. **9** illustrating a modification of the response by a third device;

FIG. **12** is a block diagram of a sixth particular embodiment of a system to select a device identifier value;

FIG. **13** is a flow diagram of a first particular embodiment of a method of selecting an identifier value;

FIG. **14** is a flow diagram of a second particular embodiment of a method of selecting an identifier value;

FIG. **15** is a block diagram of a seventh particular embodiment of a system to select a device identifier value;

FIG. **16** is a block diagram of an eighth particular embodiment of a system to select a device identifier value;

FIG. **17** is a block diagram of a ninth particular embodiment of a system to select a device identifier value;

FIG. **18** is a block diagram of a tenth particular embodiment of a system to select a device identifier value;

FIG. **19** is a flow diagram of a third particular embodiment of a method of selecting an identifier value;

FIG. **20** is a flow diagram of a fourth particular embodiment of a method of selecting an identifier value;

FIG. **21** is a flow diagram of a fifth particular embodiment of a method of selecting an identifier value;

FIG. **22** is a flow diagram of a sixth particular embodiment of a method of selecting an identifier value;

FIG. **23** is a flow diagram of a seventh particular embodiment of a method of selecting an identifier value;

FIG. **24** is a block diagram of a particular embodiment of a system including a hub device;

FIG. **25** is a block diagram of a particular embodiment of the hub device depicted in FIG. **24**;

FIG. **26** is a flow diagram of a first particular embodiment of a method of operation of a hub device; and

FIG. **27** is a flow diagram of a second particular embodiment of a method of operation of a hub device.

DETAILED DESCRIPTION

FIG. **1** is a block diagram of a first particular embodiment of a system to select a device identifier value. The system **100** includes a host device **110** in communication with a memory device **120** via a memory device network **102**. The host device

110 includes a memory device interface 112 coupled to the memory device network 102. For example, the memory device network 102 may be a bus and the memory device interface 112 may include a host bus interface. The host device 110 is configured to send messages, such as commands, data, or any combination thereof, to the memory device 120 and receive messages such as responses, via the memory device network 102. The host device 110 may include an electronic device such as a computer, a mobile phone, a personal digital assistant (PDA), a gaming device, a communication device, a multimedia player device, any other device adapted to communicate with one or more memory devices, or any combination thereof.

The memory device 120 receives data indicating one or more used identifier values 104, such as identifier values provided by other devices (not shown) coupled to the memory device network 102 during an enumeration operation. In response to receiving a device identification message, such as an enumeration message 114, the memory device 120 may select a distinctive device identifier value 124. The distinctive device identifier value 124 is a value other than any of the one or more used identifier values 104. The memory device 120 selectively sends a response 126 indicating the selected distinctive device identifier value 124 to the host device 110 via the memory device network 102. For example, the distinctive device identifier value 124 may be sent to the host 110 in a response as a relative card address (RCA), also sometimes referred to as a "Device ID." By selecting the distinctive device identifier value 124 to avoid the used identifier values 104, the device identifier value 124 may be accepted by the host device 110 without requiring additional identifier value selection by the memory device 120.

The host device 110 is configured to communicate with devices coupled to the memory card network 102 using an identifier value for each device that is distinct from the identifier values of the other devices. The host device 110 may perform an enumeration operation, such as during an initialization period, to request and receive an identifier from each device. The host 110 sends the enumeration message 114, such as an enumeration command or other initialization command, to prompt the memory device 120 to select a device identifier value and receives the selected distinctive device identifier value 124 via the response 126.

The memory device 120 may be a flash memory card, such as an enhanced SD™ or microSD™ card that is adapted to select the distinctive device identifier value 124 as a value different from any of the one or more used identifier values 104. (SD and microSD are trademarks of SD-3C, LLC.) The memory device 120 includes a host interface 122 to enable communication with the host device 110 via the memory device network 102. The memory device 120 may also include a non-volatile memory (not shown), such as a flash memory array, that is accessible to the host device 110 after the distinctive device identifier value 124 has been selected and used by the host device 110 to address messages to the memory device 120.

The memory device 120 is configured to receive messages during an initialization process and to identify one or more received enumeration messages as an enumeration command originated by the host device 110 or as a response message, such as an enumeration message that includes the data indicating zero, one, or more used identifier values 104 and that is originated by one or more other devices (not shown) coupled to the host device 110 via the memory device network 102. An enumeration message may be an enumeration command, an enumeration response, or any other type of message related to an enumeration process or that contains enumeration related information. In response to identifying a received message as an enumeration command, the memory device 120 may selectively send the response 126 including the distinctive device identifier value 124 to the host device 110. In response to identifying the enumeration message as a response message indicating the one or more used identifier values 104, the memory device 120 may read the one or more used identifier values 104 from the response message. The memory device 120 may store, at least temporarily, the identifier values used by other devices coupled to the memory device interface 112 of the host device to enable selection of the distinctive device identifier value 124.

Because the memory device 120 selects the distinctive device identifier value 124 to avoid identifier values used by other devices, a device enumeration may be performed without duplicating any previously-selected identifier values or other non-allowed values. As a result, enumeration of a large number of memory devices coupled to the memory device network 102 may be performed significantly faster than systems where the memory devices rely on the host to determine whether a selected identifier value is distinct from another device's identifier value.

Although the memory device 120 is described as identifying the enumeration message 114 as an enumeration command or an enumeration response message, in other embodiments the memory device 120 may instead respond to the enumeration message based on an internal state of the memory device (e.g. whether the memory device has selected its identifier value or has not selected its identifier value) and the content of the received enumeration message 114. For example, if the enumeration message 114 includes one or more device identifiers in the message content, the memory device 120 may treat the enumeration message 114 as a response message from another device and may store the device identifiers from the message and forward the message to a next device. If the enumeration message 114 includes an identifier of the host device 110, the memory device 120 may treat the enumeration message 114 as a message sent by another device and store any identifier values in the enumeration message 114. If the enumeration message 114 includes an identifier of "broadcast," such as an all-"1" value identifier, as an illustrative non-limiting example, the memory device 120 may generate the distinctive device identifier value 124 and send the distinctive device identifier value 124 to the host 110 via another enumeration message.

Further, the memory device 120 may be operative to select the distinctive device identifier value 124 in accordance with one or more selection rules during an enumeration operation such as upon a system initialization or when the memory device 120 is connected to the memory device network 102 after an enumeration operation has completed. For example, during the enumeration operation the memory device 120 may select the distinctive device identifier value 124 based on one or more selection rules that cause the memory device 120 to operate as described with respect to FIGS. 2-4, FIG. 5, FIGS. 6-8, FIGS. 9-11, or any combination thereof. Selection rules are further described with respect to FIG. 12. As another example, when the memory device 120 is coupled to the host device 110 after the enumeration process has been completed, the host device 110 may transmit the largest device identifier value already selected by another device. In response, the memory device 120 may select the distinctive device identifier value 124 according to selection criteria to be a number larger than the largest device identifier value provided by the host device 110.

FIG. 2 is a block diagram of a second particular embodiment of a system 200 to select a device identifier value. The system **200** shows a first device response to a first enumeration command and has a ring topology. The system **200** includes a host device **210** coupled to a representative first device (Device 1) **220**, a representative second device (Device 2) **240**, and a representative third device (Device 3) **260**, via a memory device network **202**. Each device **220**, **240**, and **260** may be configured to store data indicating one or more used identifier values retrieved from responses indicating device identifier value selections of other devices and to select a distinctive identifier value (i.e. an identifier value other than the used identifier values).

The host device **210** includes a storage element, such as a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage that is configured to store data corresponding to selected identifier values, illustrated as a table of enumerated devices **211**. The host device **210** also includes a memory device interface **212** to enable communication with the devices **220**, **240**, and **260** via the memory device network **202**. The memory device interface **212** has a transmitter circuit **216** to send messages to the devices **220**, **240**, and **260** and a receiver circuit **218** to receive messages from the devices **220**, **240**, and **260**. As an illustrative example, the host device **210** may correspond to the host device **110** of FIG. **1**.

The memory device network **202** may include one or more pairs of data lines to transmit data between devices. The memory device network **202** has a ring topology and messages travel in a single direction along a communication path **204** around the ring. The first device **220** has a first position on the communication path **204**, the second device **240** has a second position on the communication path **204**, and the third device **260** has a third position on the communication path **204**. The sequential order of the positions of the devices **220**, **240**, and **260** corresponds to a sequential order that messages travel from device to device along the communication path **204**. For example, a message sent by the host device **210** to a destination device may include a device identifier value in the message header to indicate the destination device. Each device **220**, **240**, and **260** that receives the message may examine the message header to determine whether the device is the intended recipient. If the device is not the intended recipient, the device forwards the message (or a copy of the message) to the next device on the communication path **204**. The message may be a command that includes a destination identification (DID) field that indicates no specific destination, such as by having a "broadcast" value, in which case any device that is in a state that can accept the command will accept the command as an addressed recipient.

The first device **220** includes a host interface **222** that has a receiver circuit **226** and a transmitter circuit **228**. The receiver circuit **226** is configured to receive messages, such as commands and data, from a previous device on the communication path **204**, i.e. the host device **210**, via the memory device network **202**. The transmitter circuit **228** is configured to transmit messages, such as responses, to a next device on the communication path **204**, i.e. the second device **240** via the memory device network **202**.

The first device **220** includes one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that are configured to store data corresponding to used identifier values that have been selected by one or more devices. The storage elements are illustrated as a table **230** storing one or more used identifier values **231**. The first device **220** also includes a device identifier tangible storage to store a device identifier value **224** of the first device **220**. The first device **220** may include

one or more controllers, memory arrays, wireless transceivers, or any combination thereof, as described with respect to FIG. **11** and FIGS. **15-18**. As an illustrative example, the first device **220** may correspond to the memory device **122** of FIG. **1**. To illustrate, the first device **220** may be a flash memory card.

The first device **220** is configured to receive an enumeration message via the host interface **222** and to identify the received enumeration message as a command originated by the host device **210**, such as a first enumeration command (ENUM CMD 1) **214** sent by the host device **210**, or as a response message originated by another device. For example, the first device **220** may read header information of a received message and determine a message type based on a message type indicator included in the header information that indicates whether the message is a command or a response message. In response to identifying the enumeration message as the response message, the device **220** may be configured to read an identifier value from the response message and store, at least temporarily, the identifier value at the table **230** as used by another device coupled to the memory device interface **212** of the host device **210**. The first device **220** may be configured to accumulate multiple used identifier values at the table **230** that are received via one or more response messages.

In response to identifying the enumeration message as a command, the first device **220** is configured to selectively initiate sending of an enumeration response message indicating the distinctive device identifier value **224** to the host device **210**. For example, upon determining that the enumeration message is a command, the first device **220** may select the distinctive device identifier value **224** to be a value other than any identifier value indicated as used by any other device coupled to the memory device interface of the host device **210**. To illustrate, the first device **220** may be configured to perform a computation that generates the distinctive device identifier value based on each of the used identifier value(s) **231** at the table **230**, such as by adding all stored used identifier value(s) **231** and adding one to the resulting sum.

Alternatively, or in addition, the first device **220** may be configured to select or generate one or more trial identifier values and to compare each trial identifier value to the used identifier value(s) **231** in the table **230** until an identifier value is determined to be distinct from each of the used identifier value(s) **231**. As used here, a "trial identifier value" may be a value generated by a device to be tested for distinctiveness based on each identifier value that is indicated as being used. The trial identifier value may be selected as the distinctive device identifier value **224** when the trial identifier value is determined to be distinctive or may be discarded when the trial identifier value is found to duplicate a used identifier value. For example, each of the one or more trial identifier values may be compared to each of the used identifier value(s) **231**. The first device **220** may continue iteratively selecting and comparing trial values until a value is determined to not match any of the used identifier value(s) **231**. As another example, where the used identifier value(s) **231** are sorted, such as in an ascending or descending order, a trial identifier value may be compared to some but not all of the used identifier value(s) **231** to determine whether the trial identifier value duplicates any of the used identifier value(s) **231**. Trial values may be generated randomly or pseudo-randomly, selected from one or more stored values provided by a device manufacturer, generated by another mechanism, or any combination thereof.

After selecting, computing, or otherwise generating an identifier value **224** that is distinct from each of the one or more used identifier values **231**, the first device **220** stores the distinctive device identifier value **224** and generates and sends an enumeration response message, such as a response **226**, to the host. The response **226** indicates the distinctive device identifier value **224** and is transmitted to the next device on the communication path for eventual delivery to the host device **210** via one or more other devices (e.g. the second device **240** and the third device **260**).

The enumeration message (e.g. the first command **214** and/or the response **226**) may optionally include error detection data that enables the host device **210** to detect an occurrence of one or more errors that occur as the response **226** is routed to the host device **210**. For example, the error detection data may include cyclic redundancy check (CRC) data **227**. Alternatively, or in addition, the response **226** may include redundancy data, parity data, or any other error detection or error correction data.

The first device **220** may not respond to all received enumeration messages identified as commands by selecting the distinctive device identifier value **224** and sending a response. For example, a command received at the first device **220** is forwarded without sending an enumeration response message in response to the first device **220** determining that the command indicates one or more recipients but does not indicate the first device **220** as a recipient. To illustrate, the first device **220** may read header information of the command that indicates one or more device identifier values but that does not match the distinctive device identifier value **224** of the first device **220**. In this case, the first device **220** forwards the command to the second device **240** without sending a response message to the host **210**.

The second device **240** includes a host interface **242** that has a receiver circuit **246** and a transmitter circuit **248**. The second device **240** includes one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof. The one or more storage elements are configured to store data corresponding to identifier values that have been selected by a device, illustrated as a table **250** storing one or more used identifier values **251**. The second device **240** also includes a device identifier tangible storage to store a distinctive device identifier value **244** of the second device **240**.

The third device **260** includes a host interface **262** that has a receiver circuit **266** and a transmitter circuit **268**. The third device **260** includes one or more storage elements such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof. The one or more storage elements are configured to store data corresponding to identifier values that have been selected by a device, illustrated as a table **270** storing one or more used identifier values **271**. The third device **260** also includes a device identifier tangible storage to store a distinctive device identifier value **264** of the third device **260**.

The second device **240**, the third device **260**, or any combination thereof, may include one or more controllers, memory arrays, wireless transceivers, or any combination thereof. The second device **240** and the third device **260** may be configured to operate in a substantially similar manner as the first device **220** during a device enumeration operation.

During operation, the host device **210** may send a first enumeration command (ENUM CMD 1) **214** over the communication path **204** and the first enumeration command **214** is received by the first device **220**. The first enumeration command **214** may be sent as part of an enumeration operation that the host device **210** initiates during an initialization process. Each device **220**, **240**, and **260** may be in an initialization state that causes the devices **220**, **240**, and **260** to be responsive to enumeration commands and to other devices' responses to enumeration commands. Each device **220**, **240**, and **260** may be initialized to have an empty table **230**, **250**, **270** of used identifier values and no selected device identifier value **224**, **244**, **264**. As an example, the host device **210** may initiate a power-up event to the devices **220**, **240**, and **260** by providing power via the memory device network **202**, and in response to detecting the power-up event, each device **220**, **240**, and **260** may enter an initialization state.

The first device **220** may receive the first enumeration command **214** while the table **230** is empty, i.e. before any device has selected a device identifier value. In response, the first device **220** may access the table **230** and perform a computation to generate a distinctive device identifier value of "2." For example, the first device **220** may sum all used identifier value(s) **231** (e.g., the sum may be zero when the table is empty) and add a constant to generate the result "2." Alternatively, the first device **220** may generate or select a trial identifier value of "2." For example, the first device **220** may generate a random identifier value, select an identifier value from a table, or use a pre-set initial identifier value, as illustrative, non-limiting examples. The first device **220** may compare the trial identifier value to the table **230**, determine that the table **230** stores no used identifier values, and select the trial identifier value as the distinctive device identifier value **224**. The first device **220** may generate the response **226**, indicate the host device **210** as the intended recipient of the response **226**, and send the response **226** along the communication path **204** to the second device **240**. Prior to sending the response **226**, the first device **220** may optionally perform a CRC operation on data included in the response **226** and include resulting CRC data **227** to enable detection of one or more transmission errors.

The second device **240** receives the first response **226** and reads the device identifier value **224** ("2") from the response **226**. The second device **240** records the device identifier value **224** ("2") to the table **250** as a used indicator value **251** and forwards the response **226** to the third device **260**. The third device **260** similarly reads the response **226** and records the device identifier value **224** ("2") to the table **270** and forwards the reply **226** to the host device **210**.

The host device **210** receives the response **226** and records the identifier value of "2" as corresponding to the first device **220**. The first device **220** may enter an initialization complete state upon sending the response **226**, for example, or may enter the initialization complete state upon receiving a signal from the host device **210** that the identifier value has been accepted, as another example.

Referring to FIG. **3**, after recording the identifier value of the first device **220**, the host device **210** sends a second enumeration command (ENUM CMD 2) **314**. The first device **220**, having entered the initialization complete state, may forward the second enumeration command **314** to the second device **240** without generating a response.

The second device **240** receives the second enumeration command **314** while the table **250** stores only the used identifier value "2" of the first device **220** and in response to receiving the second enumeration command **314** selects or generates a trial identifier value in a manner similar to the first device **220**. For example, the second device **240** may perform a computation using the value "2" at the table **250** to generate a distinctive device identifier value of "7." As another example, the second device **240** may select or generate a trial identifier value of "2" and may compare the trial identifier value to the table **250** and determine that the trial identifier value matches a used identifier value **251** (i.e., "2" is already selected by the first device **220**). The second device **240** may select or generate a next trial identifier value of "7" and compare the value "7" to the used identifier value **251** (FIG. **2**) stored at the table **250**. Upon determining that the trial identifier value of "7" is distinct from the used identifier value **251** (FIG. **1**), the second device **240** selects the trial identifier value as the device identifier value **244**. After selecting the device identifier value **244** as "7", the second device **240** may also add the value "7" to the table **250** to update stored used identifier values **351**. The value "7" may be added to the table **250**, for example, so that in case a second enumeration trial is requested of the second device **240** by the host device **210**, such as via a command having a Destination ID of "2", the second device **240** can select another identifier value by including "7" as a used identifier value.

The second device **240** may generate a response **346**, indicate the host device **210** as the intended recipient of the response **346**, and send the response **346** along the communication path **204** to the third device **260**. Prior to sending the response **346**, the second device **240** may generate CRC data **347** and include the CRC data **347** to the response **346**.

The third device **260** receives the response **346** and reads the device identifier value from the response **346**. The third device **260** records the device identifier value ("7") to the table **270** to store updated used indicator values **371** and forwards the response **346** to the host device **210**. The host device **210** receives the response **346** and records the identifier value of "7" as corresponding to the second device **240**. The second device **240** may enter an initialization complete state after sending the response **346**.

Referring to FIG. **4**, after recording the identifier value of the second device **240**, the host device **210** sends a third enumeration command (ENUM CMD 3) **414**. The first device **220** and the second device **240**, having entered the initialization complete state, may forward the third enumeration command **414** to the third device **260** without generating a response.

The third device **260** receives the third enumeration command **414** and in response selects or generates a distinctive identifier value in a manner similar to the first device **220** and the second device **240**. For example, the third device **260** may determine that an identifier value of "5" is distinct from the used identifier values **371** (FIG. **3**), and select the identifier value of "5" as the device identifier value **264**. The third device **260** may generate a response **466**, indicate the host device **210** as the intended recipient of the response **466**, and send the response **466** to the host device **210**. Prior to sending the response **466**, the third device **260** may optionally generate and include CRC data **467** to enable detection of transmission errors. The third device **260** may add the value "5" to the table **270** to update stored used identifier values **471** either prior to or after sending the response **466**.

The host device **210** receives the response **466** and records the identifier value of "5" as corresponding to the third device **260**. The third device **260** may enter an initialization complete state after sending the response **466**. Upon determining that all connected devices have been assigned distinct identifier values, the host device **210** may end the enumeration operation. For example, the host device **210** may send a fourth enumeration message (not shown) and detect that the fourth enumeration message returns to the host device **210**, indicating that all devices are in the initialization complete state.

As a result, the enumeration operation is performed with each device **220**, **240**, and **260** selecting its own distinctive identifier value **224**, **244**, **264**. The enumeration operation efficiently uses transmission cycles ensuring that every device **220**, **240**, **260** chooses an identifier value that is not already used, thus eliminating extra messaging from the host device **210** instructing devices to re-select identifier values and messaging from the devices to the host device with a next selected identifier value. As a result, the enumeration cycle can be performed efficiently for a large number of devices.

Although three representative devices **220**, **240**, and **260** are illustrated as coupled to the host device **210** via the memory device network **202**, any number of such devices may be coupled to the host device **210** via the memory device network **202**. Also, although the memory device network **202** is schematically illustrated as multiple discrete lines connecting the host device **210** and the devices **220**, **240**, and **260** for ease of explanation, various physical structures may be used to form the memory device network **202** having a ring topology for messaging in a single direction. As one illustrative example, the memory device network **202** may be implemented by a bus that is controlled to emulate a ring topology.

In addition, although described with respect to a ring topology, in other embodiments the memory device network **202** may be implemented using other topologies, such as a tree topology, a star topology, or a linear daisy chain topology. The memory device network may be implemented in one or more other topologies with a communication path between the host device and each device that enables each device to receive prior devices' identifier value selections and to select a distinctive identifier value other than the selected identifier values of the prior devices. An example of a system using a linear daisy chain topology is described with respect to FIG. **5**.

FIG. **5** is a block diagram of a third particular embodiment of a system to select a device identifier value. The system **500** includes a host device **510** having a table **511** of enumerated devices and a memory device interface **512**. The host device **510** is coupled to a first device **520**, a second device **540**, and one or more additional devices via a memory device network.

The memory device network includes a communication path having a first leg originating at the host device **510** and including the first device **510** at a first position on the communication path, the second device **520** at a second position, and continuing to a last device (not shown) at a last position on the communication path. The communication path also includes a second leg originating at the last device and ending at the host device **510**. Messages travel from the host device **510** to the devices **520**, **540** along the first leg of the communication path and from the devices **520**, **540** to the host device **510** along the second leg of the communication path.

The host device **510** is configured to send messages, such as commands, to the devices **520**, **540** via a transmitter circuit **516** of the memory device interface **510**. The host device **510** is also configured to receive messages from the devices **520**, **540** via a receiver circuit **518** of the memory device interface **512**. The host device **510** may operate substantially as described with respect to the host device **210** of FIGS. **2-4**.

The first device **520** includes a table **530** to store used indicator value(s) **531** and generates or selects a distinctive device identifier value **524** that is stored at the first device **520**. The first device **520** includes a host interface **522** that enables the first device **520** to communicate with the host device **510** via the memory device interface **512** of the host device **510**. The host interface **522** includes a first receiver circuit coupled to receive messages from the transmitter circuit **516** of the memory device interface **512** and a first transmitter circuit coupled to send messages to the receiver circuit **518** of the memory device interface **512**. The host interface **522** also includes a second transmitter circuit coupled to send messages to the second device **540** and a second receiver circuit coupled to receive messages from the second device **540**.

The first device **520** is configured to receive messages, such as commands, from the host device **510** and to determine whether to generate and send a response to the host device **510** or to forward the message to the second device **540**. For example, when the first device **520** determines that the first device **520** is an allowed or designated recipient of the message, the first device **520** may generate and send a response to the receiver circuit **518** of the host device **510** and may optionally forward the message to the second device **540**, such as when the message indicates multiple recipients. When the first device **520** is not an allowed or designated recipient of the message, such as when a message header indicates one or more designated recipients but does not indicate the first device **520**, the first device **520** may forward the message to the second device **540** without generating a response. The first device **520** is also configured to forward messages received from the second device **540** to the receiver circuit **518** of the host device **512**.

The second device **540** includes a table **550** to store used indicator value(s) **551** and selects or generates a distinctive device identifier value **544** that is stored at the second device **540**. The second device **540** includes a host interface **542** that enables the second device **540** to communicate with the host device **510** via messages forwarded by the first device **520** to and from the memory device interface **512** of the host device **510**. The host interface **542** includes a first receiver circuit coupled to receive messages from the second transmitter circuit of the host interface **522** of the first device **520** and a first transmitter circuit coupled to send messages to the second receiver circuit of the host interface **522** of the first device **520**. The host interface **542** also includes a second transmitter circuit coupled to send messages to a next device on the first leg of the communication path and a second receiver circuit coupled to receive messages from the next device on the second leg of the communication path.

During operation, the first device **520** responds to a first enumeration command (not shown) from the host device **510** by selecting the distinctive device identifier value **524** of "2" and storing the value of "2" as a used identifier value **531** at the table **530**. To enable other devices at later positions along the communication path, such as the second device **524**, to receive an indication that the identifier value of "2" is used, the first device **520** sends a response to the first enumeration command to the second device **540** instead of, or in addition to, sending the response directly to the host device **510**.

The host device **510** sends a second enumeration command **514** via the transmitter circuit **516** of the memory device interface **512**. The first device **520**, having already selected the device identifier value **524**, forwards the second enumeration command **514** to the second device **540**.

The second device **540** receives the enumeration command **514** and in response selects or generates the distinctive device identifier value **544** of "7" to be distinct from the used identifier value of "2" stored in the table **550**. The second device **540** records the value of "7" to used identifier values **551** at the table **550**. To enable other devices at later positions along the communication path to receive an indication that the identifier value of "7" is used, the second device **540** sends a response **546** indicating the used identifier value of "7" along the first leg of the communication path in a direction away from the host device **510**. In a particular embodiment, the second device **540** may also send the response **546** to the first device **520**. In an alternative embodiment, the second device **540** may not send the response **546** to the host device **510** and may instead wait until the response **546** is propagated along the first leg of the communication path, reaches the last device on the communication path, and returns via the second leg of the communication path to be forwarded by the second device **540** to the first device **520** and by the first device **520** to the host device **510**.

FIG. **6** is a block diagram of a fourth particular embodiment of a system to select a device identifier value. The system **600** includes a host device **610** coupled to a representative first device (Device 1) **620**, a representative second device (Device 2) **640**, and a representative third device (Device 3) **660**, via a memory device network **602**. Each device **620**, **640**, and **660** may be configured to store data indicating one or more used identifier values retrieved from responses indicating device identifier value selections of other devices and to select a distinctive identifier value (i.e. an identifier value other than the used identifier values).

The host device **610** includes a storage element, such as a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage that is configured to store data corresponding to selected identifier values, illustrated as a table of enumerated devices **611**. The host device **610** also includes a memory device interface **612** to enable communication with the devices **620**, **640**, and **660** via the memory device network **602**. As an illustrative example, the host device **610** may correspond to the host device **210** of FIGS. **2-4**.

The memory device network **602** may include one or more pairs of differential signaling lines to transmit data between devices. The memory device network **602** has a ring topology and messages travel in a single direction along a communication path **604** around the ring. The first device **620** has a first position on the communication path **604**, the second device **640** has a second position on the communication path **604**, and the third device **660** has a third position on the communication path **604**. The sequential order of the positions of the devices **620**, **640**, and **660** corresponds to a sequential order that messages travel from device to device along the communication path **604**. For example, a message sent by the host device **610** to a destination device may include a device identifier value in the message header to indicate the destination device. Each device **620**, **640**, and **660** that receives the message may examine the message header to determine whether the device is the intended recipient. If the device is not the intended recipient, the device forwards the message (or a copy of the message) to the next device on the communication path **604**. As an illustrative example, the memory device network **602** may correspond to the memory device network **202** of FIGS. **2-4**.

The first device **620** includes a host interface **622** configured to receive messages, such as commands and data, from a previous device on the communication path **604**, i.e. the host device **610**, via the memory device network **602** and to transmit messages, such as responses, to a next device on the communication path **604**, i.e. the second device **640** via the memory device network **602**.

The first device **620** includes one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that are configured to store data corresponding to threshold identifier value. The storage devices are illustrated as a used identifier value storage **630** storing a used identifier value as an identifier value threshold **631**. The first device **620** also includes a device identifier tangible storage to store a device identifier value **624** of the first device **620**. The first device **620** may include one or more controllers, memory arrays, wireless transceivers, or any combination thereof, as described with respect to FIG. **11** and FIG. **15-18**. As an illustrative example, the first device **620** may correspond to the memory device **120** of FIG. **1** or the first device **220** of FIGS. **2-4**.

The first device **620** is configured to receive an enumeration message via the host interface **622** and to identify the received enumeration message as a command originated by the host device **610**, such as a first enumeration command (ENUM CMD 1) **614** sent by the host device **610**, or as a response message. For example, the first device **620** may read header information of a received message and determine a message type based on a message type indicator included in the header information that indicates whether the message is a command or a response message. In response to identifying the enumeration message as the response message, the device **620** may be configured to read an identifier value indicated as used by another device from the response message and store, at least temporarily, the used identifier value at the used identifier value storage **630** as the identifier value threshold **631**. As an example, the first device **620** may be configured to accumulate multiple used identifier values that are received via one or more response messages at the used identifier value storage **630** and to use a most recently stored identifier value as the identifier value threshold **631**. As another example, the first device **620** may be configured to replace a stored used identifier value at the used identifier value storage **630** with the identifier value read from the response message.

In response to identifying the enumeration message as a command, the first device **620** is configured to selectively initiate sending of an enumeration response message indicating the distinctive device identifier value **624** to the host device **610**. For example, upon determining that the enumeration message is a command, the first device **620** may select the distinctive device identifier value **624** by adding an offset value **637** to a most recently stored used identifier value (i.e. the identifier value threshold) at the used identifier value storage **630** to generate a result that is greater than the most recently stored used identifier value. As another example, the first device **620** may select the distinctive device identifier value **624** by subtracting the offset value **637** to a most recently stored used identifier value (i.e. the identifier value threshold **631**) at the used identifier value storage **630** to generate a result that is less than the identifier value threshold **631**. The offset value **637** may be selected by the first device **620**, such as a randomly or pseudo-randomly generated number. Alternatively, the offset value **637** may be determined by a device manufacturer, such as stored at the first device **620** to have a value of “1” or “2” as illustrative, non-limiting examples.

As another example, the first device **620** may be configured to use the most recently stored used identifier value (i.e. the identifier value threshold **631**) at the used identifier value storage **630** as a threshold value that defines a non-allowed identifier range of values **633** and an allowed identifier range of values **635** and may select the distinctive device identifier value **624** to be within the allowed identifier range of values **635**. To illustrate, the first device **620** may generate a random or pseudo-random value that corresponds to a value within the allowed identifier range of values **635**. As another illustrative example, the first device **620** may select a value from a table of selectable values (not shown) such that the selected value is the lowest value within the table of selectable values and also within the allowed identifier range of values **635**. As another illustrative example, the first device **620** may perform a calculation to determine a value that is within the allowed identifier range of values **635**, such as by adding the offset value **637** to a value in the non-allowed identifier range of values **633** to select an identifier value within the allowed identifier range of values **635**.

When each device in the enumeration process uses a most recently received used identifier value as a threshold to select or generate a device identifier value, each device ensures that its selected device identifier value is distinct from all other identifier values that are indicated as used. After selecting or generating the distinctive device identifier value **624**, the first device **620** is configured to generate and send an enumeration response message, such as a response **626**, to the host. The response **626** indicates the distinctive device identifier value **624** and is transmitted to the next device on the communication path for eventual delivery to the host device **610** via one or more other devices (e.g. the second device **640** and the third device **660**). The response **626** may optionally include error detection data that enables the host device **610** to detect an occurrence of one or more errors that occur as the response **626** is routed to the host device **610**, as described with respect to FIGS. **2-4**.

The first device **620** may not respond to all received enumeration messages identified as commands by selecting the distinctive device identifier value **624** and sending a response. For example, a command received at the first device **620** is forwarded without sending an enumeration response message in response to the first device **620** determining that the command indicates one or more recipients but does not indicate the first device **620** as a recipient. To illustrate, the first device **620** may read header information of the command that indicates one or more device identifier values but that does not match the distinctive device identifier value **624** of the first device **620**. In this case, the first device **620** forwards the command to the second device **640** without sending a response message to the host **610**.

The second device **640** includes a host interface **642** and one or more storage elements such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that is configured to store data corresponding to identifier values that have been selected by a device. The storage elements are illustrated as a used identifier value storage **650** storing one or more used identifier values as an identifier value threshold **651**. The second device **640** may also store an offset value **657**. The second device **640** may be configured to use the identifier value threshold **651** as a threshold value that defines a non-allowed identifier range of values **653** and an allowed identifier range of values **655**. The second device **640** also includes a device identifier tangible storage to store a distinctive device identifier value **644** of the second device **640**.

The third device **660** includes a host interface **662** and includes one or more storage elements such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that is configured to store data corresponding to identifier values that have been selected by a device. The storage elements are illustrated as a used identifier value storage **670** storing one or more used identifier values as an identifier value threshold **671**. The third device **660** may also store an offset value **677**. The third device **660** may be configured to use the identifier value threshold **671** as a threshold value that defines a non-allowed identifier range of values **673** and an allowed identifier range of values **675**. The third device **660** also includes a device identifier tangible storage to store a distinctive device identifier value **664** of the third device **660**.

The second device **640**, the third device **660**, or any combination thereof, may include one or more controllers, memory arrays, wireless transceivers, or any combination thereof. The second device **640** and the third device **660** may be configured to operate in a substantially similar manner as the first device **620** during a device enumeration operation.

During operation, the host device **610** may send a first enumeration command (ENUM CMD 1) **614** over the communication path **604** and the first enumeration command **614** is received by the first device **620**. The first enumeration command **614** may be sent as part of an enumeration operation that the host device **610** initiates during an initialization process. Each device **620**, **640**, and **660** may be in an initialization state that causes the devices **620**, **640**, and **660** to be responsive to enumeration commands and to other devices' responses to enumeration commands. Each device **620**, **640**, and **660** may be initialized to have an empty used identifier value storage **630**, **650**, **670** and no selected device identifier value **624**, **644**, **664**. As an example, the host device **610** may initiate a power-up event to the devices **620**, **640**, and **660** by providing power via the memory device network **602**, and in response to detecting the power-up event, each device **620**, **640**, and **660** may enter an initialization state.

The first device **620** may receive the first enumeration command **614**. In response, the first device **620** may access the used identifier value storage **630** and perform a computation to generate a distinctive device identifier value **624** of "2." For example, the first device **620** may add the offset value **627** of "2" to the identifier value threshold **631**, which may be initialized to a "0" value to generate the result "2." Alternatively, the first device **620** may use the identifier value threshold **631** to define an allowed identifier range of values select a trial identifier value of "2" from an allowed identifier range of values. For example, the first device **620** may generate a random identifier value, select an identifier value from a table, or use a pre-set initial identifier value, as illustrative, non-limiting examples. The first device **620** may generate the response **626** indicating the distinctive device identifier value as "2" and indicating the host device **610** as the intended recipient of the response **626** and may send the response **626** along the communication path **604** to the second device **640**. Prior to sending the response **626**, the first device **620** may optionally perform a CRC operation on data included in the response **626** and include the resulting CRC data in the response **626** to enable detection of one or more transmission errors. The first device **620** may update the identifier value threshold **631**, the non-allowed identifier range of values **633**, and the allowed identifier range of values **635**.

The second device **640** receives the first response **626** and reads the device identifier value **624** ("2") from the response **626**. The second device **640** records the device identifier value **624** ("2") to the used identifier value storage **650** as an identifier value threshold **651** and forwards the response **626** to the third device **660**. The second device **640** may use the identifier value threshold **651** to define the non-allowed identifier range of values **653** and the allowed identifier range of values **655**. The third device **660** similarly reads the response **626** and records the device identifier value **624** ("2") as the identifier value threshold **671**, and forwards the reply **626** to the host device **610**. The third device **660** may use the identifier value threshold **671** to define an updated non-allowed identifier range of values **673** and an updated allowed identifier range of values **675**.

The host device **610** receives the response **626** and records the identifier value of "2" as corresponding to the first device **620**. The first device **620** may enter an initialization complete state upon sending the response **626**, as one example, or as another example the first device **620** may enter the initialization complete state upon receiving a signal from the host device **610** that the identifier value has been accepted.

Referring to FIG. **7**, after recording the identifier value of the first device **620**, the host device **610** sends a second enumeration command (ENUM CMD 6) **714**. The first device **620**, having entered the initialization complete state, may forward the second enumeration command **714** to the second device **640** without generating a response.

The second device **640** receives the second enumeration command **714** and in response selects or generates a distinctive identifier value in a manner similar to the first device **620**. For example, the second device **640** may add the offset value **657** to the identifier value threshold **651** to generate a distinctive device identifier value of "5." As another example, the second device **640** may select or generate the value of "5" as within the allowed identifier range of values **655**. The second device **640** stores the value "5" the distinctive device identifier value **644**. The second device **640** may use the identifier value threshold **751** to define an updated non-allowed identifier range of values **753** and an updated allowed identifier range of values **755**.

The second device **640** may generate a response **746**, indicate the host device **610** as the intended recipient of the response **746**, and send the response **746** along the communication path **604** to the third device **660**. The second device **640** may also add the value "5" to the used identifier value storage **650** to update an identifier value threshold **751**. Prior to sending the response **746**, the second device **640** may generate and include CRC data in the response **746**.

The third device **660** receives the response **746** and reads the device identifier value from the response **746**. The third device **660** records the device identifier value **644** ("5") to the used identifier value storage **670** to store an updated indicator value threshold **771** and forwards the response **746** to the host device **610**. The host device **610** receives the response **746** and records the identifier value of "5" as corresponding to the second device **640**. The second device **640** may enter an initialization complete state after sending the response **746**.

Referring to FIG. **8**, after recording the identifier value of the second device **640**, the host device **610** sends a third enumeration command (ENUM CMD 3) **814**. The first device **620** and the second device **640**, having entered the initialization complete state, may forward the third enumeration command **814** to the third device **660** without generating a response.

The third device **660** receives the third enumeration command **814** and in response selects or generates a distinctive identifier value in a manner similar to the first device **620** and the second device **640**. For example, the third device **660** may determine that an identifier value of "7" is distinct from all identifier values indicated as used based on the identifier value threshold **771**, and select the identifier value of "7" as the device identifier value **664**. The third device **660** may generate a response **866**, indicate the host device **610** as the intended recipient of the response **866**, and send the response **866** to host device **610**. Prior to sending the response **866**, the third device **660** may optionally generate and include CRC data to enable detection of error occurrence during transmission. The third device **660** may also add the value "7" to the used indicator value storage **670** as an updated identifier value threshold **871**. The third device **660** may use the identifier value threshold **871** to define an updated non-allowed identifier range of values **873** and an updated allowed identifier range of values **875**.

The host device **610** receives the response **866** and records the identifier value of "7" as corresponding to the third device **660**. The third device **660** may enter an initialization complete state after sending the response **866**. Upon determining that all connected devices have been assigned distinctive identifier values, the host device **610** may end the enumeration operation. For example, the host device **610** may send a fourth enumeration message (not shown) and detect that the fourth enumeration message returns to the host device **610**, indicating that all devices are in the initialization complete state.

As a result, the enumeration operation is performed with each device **620**, **640**, and **660** selecting its own distinct identifier value **624**, **644**, **664** using a most recently received used identifier value (if any) as a threshold value to ensure each device selects a distinctive device identifier value. The enumeration operation efficiently uses transmission cycles by ensuring that each device **620**, **640**, **660** chooses an identifier value that is already used, thus eliminating extra messaging from the host device **610** instructing devices to re-select identifier values and messaging from the devices to the host device with a next selected identifier value. As a result, the enumeration cycle can be performed efficiently for a large number of devices.

Although three representative devices **620**, **640**, and **660** are illustrated coupled to the host device **610** via the memory device network **602**, any number of devices may be coupled to the host device **610** via the memory device network **602**. Also, although the memory device network **602** is schematically illustrated as multiple discrete lines connecting the host device **610** and the devices **620**, **640**, and **660** for ease of explanation, various physical structures may be used to form the memory device network **602** having a ring topology for messaging in a single direction. As one illustrative example, the memory device network **602** may be implemented by a bus that is controlled to emulate a ring topology.

In addition, although described with respect to a ring topology, in other embodiments the memory device network **602** may be implemented using other topologies, such as a tree topology, a star topology, or a linear daisy chain topology (similar to the system **500** of FIG. **5**). A communication path between the host device and each device enables each device to receive prior devices' identifier value selections and to select a distinctive identifier value other than the selected identifier values of the prior devices.

FIG. **9** is a block diagram of a fifth particular embodiment of a system to select a device identifier value. The system **900** includes a host device **910** coupled to a representative first device (Device 1) **920**, a representative second device (Device 2) **940**, and a representative third device (Device 3) **960**, via a memory device network **902**. Each device **920**, **940**, and **960** may be configured to store data indicating one or more used identifier values retrieved from responses indicating device identifier value selections of other devices and to select a distinct identifier value (i.e. an identifier value other than the used identifier values).

The host device **910** includes a storage element, such as a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage that is configured to store data corresponding to selected identifier values, illustrated as a table of enumerated devices **911**. The host device **910** also includes a memory device interface **912** to enable communication with the devices **920**, **940**, and **960** via the memory device network **902**. As an illustrative example, the host device **910** corresponds to the host device **210** of FIG. **2**, the memory device network **902** corresponds to the memory device network **202** of FIG. **2**, and a communication path **904** corresponds to the communication path **204** of FIG. **2**.

The first device **920** includes a host interface **922** and includes one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that is configured to at least temporarily store data corresponding to used identifier values that have been selected by one or more devices. The storage elements are illustrated as a table **930** storing one or more used identifier values **931**. The first device **920** also includes a device identifier tangible storage to store a device identifier value **924** of the first device **920**. The first device **920** may include one or more controllers, memory arrays, wireless transceivers, or any combination thereof, as described with respect to FIG. **11** and FIGS. **15-18**. As an illustrative example, the first device **920** may correspond to the memory device **220** of FIG. **2**.

As described below, each of the devices **920**, **940**, and **960** may receive data indicating all used identifiers in a single message. As a result, each device may read the used identifiers into one or more temporary buffers or RAM to generate a distinctive identifier value without continuing to store the used identifier values after the device selects its own distinctive identifier value. Tables **930**, **950**, and **970** are illustrated for ease of explanation and may not correspond to actual data structures in the devices.

The first device **920** is configured to receive an enumeration message via the host interface **922** and to identify the received enumeration message as a command originated by the host device **910**, such as a first enumeration command (ENUM CMD 1) **914** sent by the host device **910**, or as a response message. For example, the first device **920** may read header information of a received message and determine a message type based on a message type indicator included in the header information that indicates whether the message is a command or a response message. In response to identifying the enumeration message as the response message, the device **920** may be configured to read one or more identifier values from the response message and may store, at least temporarily, the read identifier value(s) at the table **930** as used by another device coupled to the memory device interface **912** of the host device **910**. The first device **920** may be configured to accumulate multiple used identifier values at the table **930** that are received via a single response message.

The first device **920** may be configured, upon identifying the enumeration message as the response message, to select a device identifier value that is distinctive from each used identifiers read from the response message and to generate a second response message that includes each used identifier value identified by the response message and that also includes the distinctive device identifier value. The first device **920** may select a distinctive identifier value using one or more of the identifier value selection techniques described with respect to the first device **220** of FIG. **2**. As described further below, the received response message may include a used identifier value of each device (if any) that has a corresponding position on the communication path **904** between the host device **910** and a position of the first device **920**. The first device **920** may be configured to generate the second response message by adding the distinctive device identifier value to a first unused field of a set of device identifier fields in the response message. The first device **920** may forward the response message including the distinctive device identifier value along the communication path **904** to the host device **910**.

In response to identifying the enumeration message as a command, the first device **920** is configured to selectively initiate sending of an enumeration response message, such as a response **926**, indicating the distinctive device identifier value **924** to the host device **910**. The response **926** includes a set of device identifier fields and includes the distinctive device identifier value in a first sequential field, indicating the first device's relative position along the communication path **904** (i.e., the first position to receive messaging from the host

910). The set of device identifier fields may include at least as many fields as a maximum allowed number of devices that can be coupled to the memory device interface **912**. The first device **920** transmits the response **926** to the next device on the communication path for eventual delivery to the host device **910** via one or more other devices (e.g. the second device **940** and the third device **960**). The response **926** may optionally include error detection data that enables the host device **910** to detect an occurrence of one or more errors that occur as the response **926** is routed to the host device **910**, such as CRC data (not shown).

The first device **920** may not respond to all received enumeration messages identified as commands by selecting the distinctive device identifier value **924** and sending a response. For example, a command received at the first device **920** is forwarded without sending an enumeration response message in response to the first device **920** determining that the command indicates one or more recipients but does not indicate the first device **920** as a recipient.

The second device **940** includes a host interface **942** and one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that is configured to store data corresponding to identifier values that have been selected by a device. The storage elements are illustrated as a table **950** storing one or more used identifier values **951**. The second device **940** also includes a device identifier tangible storage to store a distinctive device identifier value **944** of the second device **940**.

The third device **960** includes a host interface **962** and one or more storage elements, such as one or more of a non-volatile memory, a random access memory (RAM), one or more registers, or other tangible storage, or any combination thereof, that is configured to store data corresponding to identifier values that have been selected by a device. The storage elements are illustrated as a table **970** storing one or more used identifier values **971**. The third device **960** also includes a device identifier tangible storage to store a distinctive device identifier value **964** of the third device **960**.

The second device **940**, the third device **960**, or any combination thereof, may include one or more controllers, memory arrays, wireless transceivers, or any combination thereof. The second device **940** and the third device **960** may be configured to operate in a substantially similar manner as the first device **920** during a device enumeration operation.

During operation, the host device **910** may send a first enumeration command (ENUM CMD 1) **914** over the communication path **904** and the first enumeration command **914** is received by the first device **920**. The first enumeration command **914** may be sent as part of an enumeration operation that the host device **910** initiates during an initialization process as described with respect to FIGS. **2-4** and FIGS. **6-8**.

The first device **920** may receive the first enumeration command **914**. In response, the first device **920** generate a device identifier value of "2" and store the generated identifier value as the distinctive device identifier value **924**. In addition, the first device **920** may optionally update the table **930**. The first device **920** may generate the response **926**, indicate the host device **910** as the intended recipient of the response **926**, indicate the distinctive device identifier value **924** of "2" in a first sequential identifier field of the response **926**, and send the response **926** along the communication path **904** to the second device **940**. Prior to sending the response **926**, the first device **920** may optionally include error detection data such as CRC data to the response **926**.

Referring to FIG. **10**, the second device **940** receives the response **926** and reads the used identifier value **924** of "2" from the response. The second device **940** may add the used identifier value **924** of "2" to the table **950** and selects or generates a distinctive identifier value of "7" in a manner similar to the first device **920**. The second device **940** stores the generated identifier value as the distinctive device identifier value **944**. The second device **940** may update the table **950** to include updated used identifier values **1051**. The second device **940** generates a second response **1046** that includes the device identifier value **924** ("2") of the first device **920** in the first sequential identifier field and the distinctive device identifier value **944** ("7") in a first unused identifier field, i.e., the second sequential identifier field. The second device **940** may indicate the host device **910** as the intended recipient of the second response **1046** and send the response **1046** along the communication path **904** to the third device **940**. Prior to sending the response **1046**, the second device **940** may include error detection data, such as CRC data, in the response **1046**.

Referring to FIG. **11**, the third device **960** receives the response **1046** and reads the used identifier values of "2" and "7" from the response **1046**. The third device **960** may add the used identifier values of "2" and "7" to the table **970** and selects or generates a distinctive identifier value of "5" in a manner similar to the first device **920**. The third device **960** stores the generated identifier value of "5" as the distinctive device identifier value **964** and may update the table **970** to include updated used identifier values **1171**. The third device **960** generates a third response **1166** that includes the device identifier value "2" of the first device **920** in the first sequential identifier field, the device identifier value "7" of the second device **940** in the second sequential identifier field, and the distinctive device identifier value **964** of "5" in a first unused identifier field, i.e., the third sequential identifier field. The third device **960** may indicate the host device **910** as the intended recipient of the response **1166** and send the response **1166** along the communication path **904** to the host device **910**. Prior to sending the response **1166**, the third device **960** may include error detection data, such as CRC data, in the response **1166**.

As a result, the enumeration operation is performed with the host device **910** sending a single enumeration command. The first device **920** generates the response **926** and each other device on the communication path **904** (e.g. the second device **940** and the third device **960**) receives a single response that indicates all identifier values used by devices having earlier positions on the communication path **904**. Each device selects its own distinctive identifier value, adds the selected distinctive identifier value to the next unused identifier field, and forwards the response to a next device on the communication path **904**. The enumeration operation efficiently uses transmission cycles by ensuring that each device **920**, **940**, **960** chooses an identifier value that is not already used, thus eliminating extra messaging from the host device **910** instructing devices to re-select identifier values and messaging from the devices to the host device with a next selected identifier value. As a result, the enumeration cycle can be performed efficiently for a large number of devices, with the host device **910** sending a single command and receiving a single response that includes a set of all selected identifier values, and the identifier values in the response are ordered according to each device's position along the communication path **904**.

Although three representative devices **920**, **940**, and **960** are illustrated as coupled to the host device **910** via the memory device network **902**, any number of devices may be coupled to the host device **910** via the memory device network **902**. In addition, although described with respect to a ring topology, in other embodiments the memory device network **902** may be implemented using other topologies, such as a tree topology, a star topology, or a linear daisy chain topology. A communication path between the host device and each device enables each device to receive prior devices' identifier value selections and to select a distinctive identifier value other than the selected identifier values of the prior devices.

Elements of the system **200** described with respect to FIGS. **2-4**, the system **600** described with respect to FIGS. **6-9**, the system **900** described with respect to FIGS. **9-11**, or any combination thereof, may be combined in a single system. For example, the devices **920**, **940**, and **960** of FIG. **9** may further be configured to use a received used identifier value as a threshold value that defines an allowed identifier range of values and to select a distinctive device identifier value to be within the allowed identifier range of values in a manner similar to the devices **620**, **640**, and **660** of FIG. **6**, in addition to the selected device identifier being distinct from each used identifier value received in a response message. To illustrate, the host device **910** may receive the response **1166** and make a determination to repeat the enumeration process. For example, the host device **910** may also be coupled to second ring of devices (not shown) and an identifier value included in the response **1166** may conflict with an identifier value from the second ring of devices. The host device **910** may generate a command to cause the devices **920**, **940**, and **960** to re-select distinctive identifier values. The host device may include in the command an identifier value threshold based on identifier values of devices on the second ring, to ensure that each of the devices **920**, **940**, and **960** selects an identifier value distinct from each other and also distinct from identifier values of devices on the second ring. As another example, the host device **910** may include in the command a list of parameters indicating identifier values selected by other devices and may broadcast or address the command to one or more of the devices **920**, **940**, and **960** to enable re-selection of device identifiers that are globally distinctive (i.e. distinct from identifiers of all devices coupled to the host device).

FIG. **12** is a block diagram of a sixth particular embodiment of a system to select a device identifier value. The system **1200** includes a storage device **1220** having multiple interfaces coupled to a controller **1232**. The controller **1232** is coupled to a Random Access Memory (RAM) **1242**, a Read Only Memory (ROM) **1250**, and a flash storage **1252**. The storage device **1220** may correspond to the memory device **120** of FIG. **1**, one or more of the devices **220**, **240**, and **260** of FIGS. **2-4**, one or more of the devices **520** and **540** of FIG. **5**, one or more of the devices **620**, **640**, and **660** of FIGS. **6-8**, one or more of the devices **920**, **940**, and **960** of FIGS. **9-11**, or any combination thereof.

As illustrated, the storage device **1220** may include any number "i" of interfaces. One or more of the interfaces may be unidirectional, such as input only or output only, or bidirectional supporting input and output messaging. One or more of the multiple interfaces may be configured to operate as a host interface **1222** and may include one or more dedicated input interfaces and one or more dedicated output interfaces that enable the host interface **1222** to operate similarly to the transmitter circuits and the receiver circuits of the host interface **222** of the first device **220** of FIG. **2** and the transmitter circuits and receiver circuits the host interface **522** of the first device **520** of FIG. **5**.

The controller **1232** includes an enumeration message identifier **1244**, a distinct identifier selector **1246**, and an enumeration response generator **1248**. One or more of the enumeration message identifier **1244**, the distinct identifier selector **1246**, and the enumeration response generator **1248** may be implemented as program instructions executed at the controller **1232**, as firmware or as dedicated circuitry within the controller **1232**, or any combination thereof.

The enumeration message identifier **1244** is configured to determine whether an enumeration message received via the host interface **1222** is a command or a response message. For example, the controller **1232** may be configured to receive an enumeration message via the host interface **1222** and to provide at least a header portion of the enumeration message to the enumeration message identifier **1244**. The enumeration message identifier **1242** may locate a message type identifier within the header portion and compare the located message type identifier with a command type indicator, a response type indicator, or both. For example, the enumeration message include a specified message type indicator at a predetermined location in the message header. The enumeration message identifier **1244** may generate an output indicating whether the enumeration message is a command or a response message.

The distinct identifier selector **1246** is configured to select a distinctive device identifier value according to one or more selection rules. For example, the distinct identifier selector **1246** may operate according to a selection rule to generate a distinctive identifier value in response to the enumeration message identifier **1244** determining that a received enumeration is a command (and not a response) by performing a computation of used identifier values **1247** to generate a result that does not duplicate any of the used identifier values **1247**, as described with respect to the system **200** of FIGS. **2-4**. To illustrate, the distinct identifier selector **1246** may retrieve all used identifier values **1247** (e.g. from the RAM **1242**, the flash storage **1252**, or other tangible storage of the storage device **1220**), and add all retrieved identifier values **1247** to generate a sum value, and then add a "1" value to the sum value to generate a distinctive result value.

As another illustration, the distinct identifier selector **1246** may select an initial trial value, such as by random or pseudo-random selection, by accessing a predetermined value, or by computing the initial trial value as a function of one or more parameters, compare the initial trial value to one or more of the used identifier values **1247**, and select the trial value as the identifier value in response to determining that the trial value does not match any of the used identifier values **1247**. If the trial value duplicates a used identifier value, the distinct identifier selector **1246** may select a next trial value, such as by random or pseudo-random selection, by accessing a predetermined next value, or by computing the next trial value as a function of one or more parameters (e.g. adding an offset to the initial trial value). The distinct identifier selector **1246** may continue iteratively selecting and comparing trial values until a value is determined to not match any of the used identifier values **1247**.

As another example, the distinct identifier selector **1246** may operate according to a selection rule to generate a distinctive identifier value in response to the enumeration message identifier **1244** determining that a received enumeration is a command (and not a response) by using a most recently received used identifier value as a threshold value, as described with respect to the system **600** of FIGS. **6-8**. To illustrate, the distinct identifier selector **1246** may retrieve a most recently used identifier value from the used identifier values **1247**. The most recently used identifier value may be retrieved from a dedicated threshold value storage maintained by the controller **1232** from a memory location that may store multiple used identifier values in an order of receipt at the storage device **1220** or may indicate an association with one or more timestamps to indicate a relative time of receipt of the stored identifiers. The distinct identifier selector **1246** may add an offset value to the most recently used identifier value as described with respect to the first device **620** of FIG. **6**, subtract an offset value from the most recently used identifier value as described with respect to the first device **620** of FIG. **6**, or use the most recently received used device indicator value to define an allowable identifier range of values as described with respect to the first device **620** of FIG. **6**. For example, in an embodiment where a maximum number of devices that can be coupled to a memory device interface of a host device is 16 such that an initial allowed range of identifiers is 0 to 15, in response to a most recently received used identifier value of "4" the distinct identifier selector **1246** may define a non-allowed identifier range of values to be 0 to 4 and an allowed identifier range of values to be 5 to 15.

As another example, the distinct identifier selector **1246** may operate according to a selection rule to generate a distinctive identifier value in response to the enumeration message identifier **1244** determining whether a received enumeration is a command or a response, as described with respect to the system **900** of FIGS. **9-11**. Generation of the distinctive identifier value may be performed according to one or more of the described techniques.

The controller **1232** may be configured to operate according to a particular one or more of the selection rules. For example, the controller **1232** may be programmable to receive one or more additional selection rules or replacement selection rules. Selection of a particular selection rule may be controlled by logic at the controller **1232** or in response to external instructions, such as an instruction from a host device.

The enumeration response generator **1248** is configured to receive the selected distinctive device identifier value from the distinct identifier selector **1246** and to generate a response message that indicates the distinctive device identifier value. For example, the enumeration response generator **1248** may write a type indicator to a response header indicating a response type message and may write a destination indicator to the response header indicating a host device as the intended recipient. The enumeration response generator **1248** may write the distinctive device identifier value or data indicating the distinctive device identifier value to a body portion of the message, such as at one or more predefined field locations of the message. The enumeration response generator **1248** may perform a parity check or perform a CRC operation to generate error detection data and may add the error detection data to a predetermined field location of the message.

The controller **1232** may further be configured to send a response message generated by the enumeration response generator **1248** to a host device via one or more interfaces of the host interface **1222**. Operation of the storage device **1220** is further described with respect to FIGS. **13-14**.

FIG. **13** is a flow diagram of a first embodiment of a method of selecting an identifier value that may be performed by the storage device **1220** of FIG. **12**. The method **1300** includes, at **1302**, receiving an enumeration message via one of the interfaces. A determination is made whether the enumeration message is a command, such as an enumeration request command, or a response, such as an enumeration response, at **1304**. For example, the determination may be made by the enumeration message identifier **1244** of FIG. **12**. The enumeration message may be part of a more generic initialization command that also takes care of enumeration. In response to the enumeration message being identified as a response, at **1304**, one or more identifier values included in the response are stored, at **1306**.

Optionally, such as when implemented in a system, such as the system **900** of FIGS. **9-11**, in response to the enumeration message being identified as the response, at **1304**, processing continues with generating a proposed distinctive identifier value as a function of stored identifier values, at **1308** and sending a response including all of the stored identifier values and the proposed distinctive identifier value over one or more of the output interfaces, at **1310**. For example, the distinctive identifier value may be generated by the distinct identifier selector **1246** of FIG. **12** and the response may be generated by the enumeration response generator **1248** of FIG. **12**.

In response to the enumeration message being identified as a command, at **1304**, a determination may be made as to whether the receiving device is an addressed recipient, at **1312**. For example, when the receiving device has transitioned to an initialization complete state, or as another example when the receiving device has already selected a device identifier value, the receiving device may determine that the receiving device is not an addressed recipient of an enumeration message sent from a host. As another example, when the command indicates one or more message recipients but does not indicate the receiving device as a recipient, the receiving device may determine itself to not be an addressed recipient. As other examples, when the command includes the receiving device's distinctive identifier value or when the command is an enumeration command and the receiving device does not yet have a distinctive identifier value, the receiving device may operate as if the receiving device is an addressed recipient.

In response to determining that the receiving device is not an addressed recipient, at **1312**, the command is retransmitted or forwarded over one or more of the output interfaces, at **1314**. In response to determining that the receiving device is an addressed recipient, at **1312**, a proposed distinctive identifier value is generated as a function of stored identifier values and parameters (if any) included in the command, at **1316**. For example, any number of parameters may be included in the command, such as to indicate an identifier value threshold, to indicate other used identifier values, or to direct the receiving device to use a particular selection rule as described with respect to FIG. **12**, as illustrative, non-limiting examples. A response is sent including the proposed distinctive identifier value over one or more of the output interfaces, at **1318**. The distinctive identifier value may be generated by the distinct identifier selector **1246** of FIG. **12** and the response may be generated by the enumeration response generator **1248** of FIG. **12**.

FIG. **14** is a flow diagram of a second particular embodiment of a method of selecting an identifier value that may be performed by the storage device **1220** of FIG. **12**. The method **1400** includes receiving an enumeration related message via one of the interfaces, at **1402**. A determination may be made whether the enumeration related message is a command addressed to the receiving device, at **1404**. In a particular example, a message is determined to be addressed to a receiving device when: (1) the device receives an enumeration message while the device does not yet have its own identifier value, or (2) the device has its identifier value set and the received message specifically contains the identifier value, or (3) the device has its identifier value set and the received message is a broadcast message and/or a multicast message. For example, the determination may be made by the enumeration message identifier **1244** of FIG. **12**. When the enumeration related message is determined to not be a command addressed to the receiving device, at **1404**, all used device identifier values in the message are stored, at **1406**, and the message is optionally retransmitted via one or more output interfaces, at **1408**.

When the enumeration related message is determined to be a command addressed to the receiving device, at **1404**, a proposed distinctive identifier value is generated as a function of stored identifier values and parameters (if any) included in the message, at **1410**. A response is sent including the proposed identifier value via one or more of the output interfaces, at **1412**. For example, the distinctive identifier value may be generated by the distinct identifier selector **1246** of FIG. **12** and the response may be generated by the enumeration response generator **1248** of FIG. **12**.

FIG. **15** is a block diagram of a seventh particular embodiment of a system to select a device identifier value. The system **1500** includes a host device **1510** coupled to a data storage device **1520** via a memory device network **1502**. The system **1500** may operate substantially as described with respect to the system **100** of FIG. **1**, the system **200** of FIGS. **2-4**, the system **500** of FIG. **5**, the system **600** of FIGS. **6-8**, the system **900** of FIGS. **9-11**, or the system **1200** of FIG. **12**.

The host device **1510** includes a controller **1516** coupled to a memory device interface **1512**. The controller **1516** may be configured to perform an enumeration operation to obtain a set of distinct identifier values corresponding to multiple devices coupled to the memory device interface **1512**. The representative data storage device **1520** represents one of the multiple devices. The enumeration operation may include sending a first enumeration message **1514**, such as an enumeration command, via the memory device interface **1512**. The first enumeration message **1514** includes a command indicator **1515** that may be embedded within a header **1516** portion of the enumeration message **1514**. The enumeration operation may also include receiving distinctive device identifier values via one or more enumeration response messages. A first distinctive identifier value may correspond to a first device of the multiple devices and a second distinctive identifier value may correspond to a second device of the multiple devices. Data indicating one or more used identifier values (e.g. including the first distinctive identifier value) is provided to the second device prior to selection of the second distinctive identifier value. Each received distinctive identifier value enables the host device **1510** to specifically identify the corresponding device as a message recipient. For example, each received distinctive identifier value may enable the host device **1510** to access the corresponding device by using the distinctive identifier value to specify the corresponding device as a message recipient. The distinctive identifier values may be received via enumeration response messages as described with respect to the response **126** of FIG. **1**, the responses **226**, **346**, and **466** of FIGS. **2-4**, the response **546** of FIG. **5**, the responses **626**, **746**, and **866** of FIGS. **6-8**, or the response **1166** of FIG. **11**, as illustrative, non-limiting examples.

The data storage device **1520** is adapted to be operatively coupled to a host device as well as one or more other devices and includes a host interface **1522** that is coupled to the memory device interface **1512** of the host device **1510** via the memory device network **1502**. A controller **1532** is coupled to the host interface **1522** and coupled to a non-volatile memory **1534**. The host interface **1522** may correspond to the host interface **222** of FIG. **2**, the host interface **522** of FIG. **5**, the host interface **622** of FIG. **6**, the host interface **922** of FIG. **9**, or the host interface **1222** of FIG. **12**, as illustrative, non-limiting examples. The non-volatile memory **1534** may be a flash memory array, as an illustrative example.

The controller **1532** includes a processor **1538**, one or more registers **1540**, and a random access memory (RAM) **1542**. The controller **1532** also includes an enumeration message identifier **1544**, a distinct device identifier selector **1546**, and an enumeration response generator **1548**. The RAM **1542** includes a used identifier value storage **1530** configured to store one or more used identifier values **1531**. The RAM **1542** may also include a device identifier value **1522** and software or other computer readable instructions **1536** that are executable by the hardware processor **1538** to execute one or more algorithms to enable the controller to select a distinctive device identifier value **1522** different from any identifier value that any of the other devices have indicated as being used (e.g. the distinctive device identifier value **1522** is a value other than any identifier value indicated as used by any other device coupled to the memory device interface **1512** of the host device **1510**).

The controller **1532** is configured to receive an enumeration message via the host interface **1522** and to identify the received enumeration message as a command originated by the host device **1510** or as a response message from one of the other devices. The controller **1532** is configured to provide the received enumeration message to the enumeration message identifier **1544**. The enumeration message identifier **1544** generates an output indicating whether the enumeration message is a command or a response message according to any one or more of the techniques described with respect to the enumeration message identifier **1244** of FIG. **12**. The enumeration message identifier **1544** may be an application run by the processor **1538** by executing at least a portion of the executable instructions **1536**, dedicated circuitry, firmware, or any combination thereof.

The controller **1532** is configured to, in response to identifying the received enumeration message as a command, selectively initiate sending an enumeration response message to the host device **1510**, the enumeration response message indicating the distinctive device identifier value **1522**. The controller **1532** is configured to provide the output of the enumeration message identifier **1544** to the distinct device indicator selector **1546**. The distinct device indicator selector **1546** accesses the used identifier values **1531** and generates an output indicating the distinct device indicator value **1522** according to any one or more of the techniques described with respect to the distinct device indicator selector **1246** of FIG. **12**. The distinct device indicator selector **1546** may be an application run by the processor **1538** by executing at least a portion of the executable instructions **1536**, dedicated circuitry, firmware, or any combination thereof.

The controller **1532** is configured to provide the output of the distinct device indicator selector **1546** indicating the distinctive device indicator value **1522** to the enumeration response generator **1548**. The enumeration response generator **1548** generates a response that includes the distinctive device identifier value according to any one or more of the techniques described with respect to the enumeration response generator **1248** of FIG. **12**. The enumeration response generator **1548** may be an application run by the processor **1538** by executing at least a portion of the executable instructions **1536**, dedicated circuitry, firmware, or any combination thereof.

The controller **1532** is configured to, in response to identifying the enumeration message as a response message from one of the other devices, read an identifier value used by such other device (e.g. an identifier value used by the device originating the received response) from the response message and store, at least temporarily, the identifier value to enable the device **1520** to select its distinctive device identifier value

1522. For example the controller **1532** is configured to store an identifier value read from a response message as a used identifier value **1531** at the used identifier value storage **1530** at the RAM **1542**.

During operation, the controller **1532** operates to enable the data storage device **1520** to function in accordance with the operations described with respect to any one or more of the embodiments of FIGS. **1-14**. For example, the controller **1532** may cause the data storage device **1520** to operate substantially as described with respect to the devices **220**, **240**, and **260** of FIG. **2**. As another example, the controller **1532** may cause the data storage device **1520** to operate substantially as described with respect to the devices **520**, **540** of FIG. **5**. As another example, the controller **1532** may cause the data storage device **1520** to operate substantially as described with respect to the devices **620**, **640**, and **660** of FIG. **6**. As another example, the controller **1532** may cause the data storage device **1520** to operate substantially as described with respect to the devices **920**, **940**, and **960** of FIG. **9**. After an enumeration process is over, or the data storage device **1520** enters an initialization complete state, or the distinct device identifier value **1522** is transmitted to the host device **1510**, or any combination thereof, the controller **1532** is responsive to memory access requests that include the distinctive device identifier value **1522** to provide access to the non-volatile memory **1534**. After selecting the distinctive device identifier value, the data storage device **1520** may forward an enumeration command to a next device without generating a response message in response to the enumeration command not specifically identifying any recipients (e.g. where the enumeration command is a broadcast enumeration command).

Although the processor **1538** is illustrated as a single processor, in other embodiments the processor **1538** may include multiple general purpose or special purpose processors, such as one or more digital signal processors (DSPs). In addition, although the RAM **1542** and the one or more registers **1540** are illustrated as embedded with the controller **1532**, in other embodiments the RAM **1542**, the one or more registers **1540**, or any combination thereof, may be separate from the controller **1532** but accessible to the controller **1532**.

FIG. **16** is a block diagram of an eighth particular embodiment of a system to select a device identifier value. The system **1600** includes the host device **1510** and the memory device network **1502** described with respect to FIG. **15**.

A data storage device **1620** includes the host interface **1522**, the controller **1532** coupled to the host interface **1522**, and the non-volatile memory **1534**, as described with respect to FIG. **15**. The controller **1532** includes the processor **1538**, the one or more registers **1540**, and the RAM **1542**. The controller **1532** also includes the enumeration message identifier **1544**, the distinct device identifier selector **1546**, and the enumeration response generator **1548**. The RAM **1542** includes the device identifier value **1522** and the software or other computer readable instructions **1536**.

As illustrated, a used identifier value storage **1630** is located at the one or more registers **1540** and configured to store the one or more used identifier values **1531**. For example, the used identifier value storage **1630** may include one or more dedicated registers sized to store a number of identifiers up to a largest number of devices that can be coupled to the memory device interface **1512** of the host device **1510**. As another example, the used identifier value storage **1630** may operate as a temporary storage, such as to temporarily store one or more of the identifier values read from a response to perform an arithmetic operation to compute the distinctive device identifier value **1546**, and to write the stored identifier values **1531** and the distinctive device identifier value **1546** to a response message.

FIG. **17** is a block diagram of a ninth particular embodiment of a system to select a device identifier value. The system **1700** includes the host device **1510** and the memory device network **1502** described with respect to FIG. **15**.

A data storage device **1720** includes the host interface **1522**, the controller **1532** coupled to the host interface **1522**, and the non-volatile memory **1534**, as described with respect to FIG. **15**. The controller **1532** includes the processor **1538**, the one or more registers **1540**, and the RAM **1542**. The controller **1532** also includes the enumeration message identifier **1544**, the distinct device identifier selector **1546**, and the enumeration response generator **1548**. The RAM **1542** includes the device identifier value **1522** and the software or other computer readable instructions **1536**. As illustrated, a used identifier value storage **1730** is located at non-volatile memory **1534** and configured to store the one or more used identifier values **1531**.

FIG. **18** is a block diagram of a tenth particular embodiment of a system to select a device identifier value. The system **1800** includes the host device **1510** and the memory device network **1502** described with respect to FIG. **15**.

A wireless communication device **1820** includes the host interface **1522** coupled to the controller **1532**. The wireless communication device **1820** also includes a wireless transceiver **1846** coupled to the controller **1532**.

The controller **1532** includes the processor **1538**, the enumeration message identifier **1544**, the distinct device identifier selector **1546**, and the enumeration response generator **1548**. The controller **1532** is configured to provide transmission content **1808** received from the host device **1510** via the host interface **1522** to the wireless transceiver **1846**. For example, the wireless transceiver **1846** may enable the wireless communication device **1846** to wireless communicate via a wireless protocol such as frequency-hopping spread spectrum radio ad-hoc network communication protocol (e.g. Bluetooth) or an Institute of Electrical and Electronics Engineers (IEEE) 802.11 protocol (e.g. Wi-Fi).

Referring to FIG. **19**, a method of selecting an identifier value at a device is illustrated. The device includes a host interface and the device is operatively coupled via the host interface to a host device as well as one or more other devices. An example of a host device is a memory card or a wireless communication device adapted to communicate with the host device via a memory device interface of the host device. The device is operative to select a distinctive device identifier value that is different from any identifier value that any of the other devices have indicated as being used. For example, if the device is the device **260** of FIG. **2**, then the device selects a distinctive device identifier value other than a device identifier value selected as used by any of the devices **220** and **240** of FIG. **2**.

In a particular embodiment, the method includes receiving an enumeration message at the device via the host interface, at **1902**, and identifying the enumeration message as a command originated by the host device or as a response message from one of the other devices, at **1904**. At decision step **1906**, the method evaluates whether the enumeration message is a command or a response. In response to identifying the enumeration message as a command, the method selectively sends an enumeration response message that indicates the distinctive device identifier value to the host device, at **1910**. The enumeration response message may be sent to the host device directly or may be sent to the host device via one or more other devices. The enumeration response message may also include cyclic redundancy check (CRC) data to allow the host to conduct error detection.

In response to identifying the enumeration message as a response message from one of the other devices, at **1906**, the method reads from the response message an identifier value used by such other device, at **1908**, and at least temporarily stores this identifier value (i.e. the identifier value read from the response message) at the device to enable the device to select its distinctive device identifier value (i.e. to select the distinctive device identifier value for the device). For example, the device **240** of FIG. **2** may read an identifier value used by the device **220** from the response message **226** of FIG. **2**. The identifier value read from the response message is at least temporarily stored at the device to enable selection of a device identifier value that is distinct from the device identifier read from the response message. The selected device identifier value enables a host device to access the device by use of the distinctive device identifier value, such as by specifying the device as a message recipient.

Referring to FIG. **20**, another embodiment of a method of selecting an identifier value at a device is shown. The method includes receiving an enumeration message via a host interface, at **2002**, and identifying the enumeration message as a command originated by a host device or as a response message, at **2004**. The command or response determination is made at **2006**. Upon determining that the enumeration message is a response, the method reads an identifier value used by another device coupled to a memory device interface of a host device from the response message, at **2008**. The method also stores the identifier value read from the response message to a used identifier value storage area, at **2010**. For example, the used identifier value storage area may be the storage area illustrated as storing the table **250** of FIG. **2**.

Upon determining that the enumeration message is a command, the method selects a distinctive device identifier value to be distinct from each used identifier value that is stored at the used identifier value storage, at **2012**. As part of making the selection of the distinctive device identifier value, the method may include comparing a device identifier value to each used identifier value that is stored at the used identifier value storage to generate the distinctive identifier value, at **2014**, and alternatively, or in addition, performs a computation that generates the distinctive device identifier value based on each used identifier value that is stored at the used identifier value storage, at **2016**. The device may be configured to accumulate multiple used identifier values at the used identifier storage. The method may compare a device identifier value to each used identifier value that is stored at the used identifier value storage to generate the distinctive identifier value. Thus, the distinctive device identifier value may be selected to be distinct from each used identifier value that is stored at the used identifier value storage.

The method then selectively sends an enumeration response message that indicates the distinctive device identifier value to the host device, at **2018**. For example, the method may include determining whether the device is an addressed recipient of the command, such as described with respect to decision **1312** of FIG. **13**. For example, the command is forwarded without sending the enumeration response message in response to the command indicating one or more recipients but not indicating the device as a recipient.

Referring to FIG. **21**, another embodiment of a method of selecting an identifier value at a device is shown. The method includes receiving an enumeration message via a host interface, at **2102**, and identifying the enumeration message as a command originated by a host device or as a response message, at **2104**. The command or response determination is made at **2106**. Upon determining that the enumeration message is a response, the method reads an identifier value used by another device coupled to the memory device interface from the response message, at **2108**. The method also stores the identifier value read from the response message to a used identifier value storage area, at **2110**. The method may also includes replacing a stored used identifier value at the used identifier value storage with the identifier value read from the response message.

Upon determining that the enumeration message is a command, the method selects a distinctive device identifier value to be distinct from each used identifier value that is stored at the used identifier value storage, at **2112**. As part of making the selection of the distinctive device identifier value, the method may add an offset value to a most recently stored used identifier value at the used identifier value storage to generate a result that is greater than the most recently stored used identifier value, as shown at **2114**. Alternatively, or in addition, the device may use a most recently stored used identifier value at the used identifier value storage as a threshold value that defines an allowed identifier range of values, and the method may select the distinctive device identifier value by selecting the device identifier value to be within the allowed identifier range of values, at **2116**. For example, if the most recently stored used identifier value has a value of two, the method would define an allowed identifier range of values as values greater than two. The method could then select a distinctive identifier value by selecting a value greater than two (e.g. three). The method then selectively sends an enumeration response message that indicates the distinctive device identifier value to the host device, at **2118**. For example, the method may select whether to send an enumeration response in based on a determination whether the device is an addressed recipient of the command, such as described with respect to decision **1312** of FIG. **13**.

Referring to FIG. **22**, another embodiment of a method of selecting an identifier value at a device is shown. The method includes receiving an enumeration message via a host interface, at **2202**, and identifying the enumeration message as a command originated by a host device or as a response message, at **2204**. The command or response determination is made at **2206**. Upon determining that the enumeration message is a command, the method selectively sends an enumeration response message that indicates a distinctive device identifier to the host device, the enumeration response message including a distinctive device identifier value, at **2208**.

Upon determining that the enumeration message is a response, the method reads an identifier value used by another device coupled to the memory device interface from the response message, at **2210**. In a particular illustrative example, the device has a second device position on a communication path and the response message originates from a first device having a first device position along the communication path. The response message may include a used identifier value of any device that has a corresponding position on the communication path between the first device position and the second device position.

The method may include selecting the distinctive device identifier value to be distinct from any used identifier value in the response message, at **2212**. For example, the method may include using a received used identifier value as a threshold value to define an allowed identifier range of values, at **2214**. The method may also include selecting the distinctive device identifier value by selecting the device identifier value to be within the allowed identifier range of values, at **2214**.

The method further includes generating a second response message that includes each used identifier value identified by the response message and that includes the distinctive device identifier value, at **2216**, and sending the second response message along the communication path, at **2220**. As an illustrative example, the method may generate the second response message by updating the response message by adding the distinctive device identifier value to a first unused field of a set of device identifier fields in the response message, at **2218**. The method may send the second response message by forwarding the updated response message including the distinctive device identifier value along the communication path to the next device, as shown at **2222**.

In another illustrative example, a third device (e.g. device **260** of FIG. **2**) has a last device position on the communication path and the distinctive device identifier value and each used identifier value included in the second response message is accessible to the third device and to any other device having a position on the communication path between the second device position and the last device position. As a result, as each device receives the propagated response, each device may read all used identifier values corresponding to devices having made identifier selection, select a distinctive identifier value, and forward the updated response to the next device along the communication path. Therefore, a single response including a set of distinctive identifier values may be received by the host device, such as the response **1166** of FIG. **11**.

Referring to FIG. **23**, a method of enumerating devices coupled to a memory device interface of a host device is shown. The memory device interface is operatively coupled to multiple devices including a first device and a second device. For example, the memory device interface **212** of the host device **210** may be coupled to the first device **220**, to the second device **240**, and to other devices such as the third device **260**, as shown in FIG. **2**. The method includes sending a first enumeration command via the memory device interface, the first enumeration command including a command indicator, at **2310**, and receiving distinctive device identifier values via one or more enumeration response messages, at **2312**. In a particular example, a first distinctive identifier value corresponds to the first device and a second distinctive identifier value corresponds to the second device. To facilitate selection of distinctive device identifiers at a device (e.g. the second device **240**) coupled to the host device, data indicating one or more used identifier values including the first distinctive identifier value is provided to the second device prior to selection of the second distinctive identifier value. The second distinctive identifier value enables the host device to specifically identify the second device as a message recipient. To illustrate, the host device may access the second device by using the second distinctive identifier value to specify the second device as a message recipient. For example, the host device **210**, upon receiving the second device identifier of the second device **240**, may communicate messages to the second device **240** by use of the second device identifier.

As a result, the enumeration operation is performed with each device selecting its identifier value to be other than previously selected identifier values (if any). The enumeration operation efficiently uses transmission cycles by eliminating the possibility that any device chooses an identifier value that is already used, thus eliminating messaging from the host device instructing devices to re-select identifier values and messaging from the devices to the host device with a next selected identifier value. As a result, the enumeration cycle can be completed efficiently for a large number of devices.

Although various components depicted herein are illustrated as block components and described in general terms, such components may include one or more microprocessors, state machines, or other circuits configured to enable the memory device **120** of FIG. **1**, the device **220**, **240**, or **260** of FIGS. **2-4**, the device **520** or **540** of FIG. **5**, the device **620**, **640**, or **660** of FIGS. **6-8**, the device **920**, **940**, or **960** of FIGS. **9-11**, the storage device **1220** of FIG. **12**, the data storage device **1520** of FIG. **15**, the data storage device **1620** of FIG. **16**, the data storage device **1720** of FIG. **17**, or the wireless communication device **1820** of FIG. **18**, to perform the particular functions attributed to such components, or any combination thereof.

In a particular embodiment, the data storage device **1520** may be a portable device configured to be selectively coupled to one or more external devices. However, in other embodiments, the memory device may be attached or embedded within one or more host devices, such as within a housing of a portable communication device. For example, the data storage device **1520** may be within a packaged apparatus such as a wireless telephone, personal digital assistant (PDA), gaming device or console, portable navigation device, or other device that uses internal non-volatile memory. In a particular embodiment, the non-volatile memory **1534** of the data storage device **1520** is a flash memory (e.g., NAND, NOR, Multi-Level Cell (MLC), Divided bit-line NOR (DINOR), AND, high capacitive coupling ratio (HiCR), asymmetrical contactless transistor (ACT), or other flash memories), an erasable programmable read-only memory (EPROM), an electrically-erasable programmable read-only memory (EEPROM), a read-only memory (ROM), a one-time programmable memory (OTP), or any other type of memory.

Referring to FIG. **24**, a particular embodiment of a system **2400** is shown. The system **2400** includes a hub device **2450** in communication with a host device **2410**. The hub device **2450** is coupled, in this example, to a first representative device **2420**, a second representative device **2440**, and a third representative device **2460** (the hub device **2450** coupled to a plurality of devices may be coupled to more than three devices). The host device **2410** includes a memory device interface **2412** that includes a transmit port **2416** and a receive port **2418**. The host device **2410** is coupled to the hub device **2450** via the transmit port **2416** and the receive port **2418**. The hub device **2450** also includes receive and transmit ports coupled to the corresponding communication ports of the host device **2410**. The hub device **2450** is coupled to the first representative device **2420** via respective transmit and receive ports as shown. The transmit and receive ports are also referred to collectively as "a port." The first representative device **2420** includes a host interface **2422** that is coupled to a corresponding interface of the hub device **2450**. Similarly, the second device **2440** includes a host interface **2442** that includes transmit and receive ports coupled to corresponding receive and transmit ports of the hub device **2450**. The third representative device **2460** includes a host interface **2462** that includes transmit and receive ports coupled to respective receive and transmit ports of the hub device **2450**. In this manner, the hub device **2450** is coupled via ports to each of the first device **2420**, the second device **2440**, and the third device **2460**.

During operation, the host device **2410** may send a first message **2402** to the hub device **2450**. As illustrated, the hub device **2450** includes a plurality of ports including a first port coupled to the first device **2420**, a second port coupled to the second device **2440**, and a third port coupled to the host device **2410**. The hub device **2450** also includes one or more additional ports such as a fourth port coupled to the third representative device **2460**. The hub device **2450** may include a controller that communicates with the third port to receive the first message **2402** via the third port from the host **2410**.

The hub device **2450** determines that the first message requests enumeration by evaluating a header field of the first message **2402**. In the illustrated embodiment, the first message **2402** includes a header field or portion, a payload portion to identify one or more identifier values, and an error checking portion, such as a Cyclic Redundancy Check (CRC) field. The header field of the first message **2402** may identify the first message as a broadcast enumeration request. For example, the first message **2402** includes a header portion that includes an indicator ("BST") of a broadcast message as well as an indicator ("ENUM") of an enumeration request. The enumeration request may be indicated by an operation code or other enumeration identifier within the header of the first message **2402**. The hub device **2450**, upon receiving the first message **2402**, evaluates the header of the first message **2402** to determine whether the first message **2402** includes a broadcast indicator and an enumeration indicator.

Upon determining that the first message **2402** requests enumeration, the controller within the hub device **2450** emulates a ring communication topology. The controller within the hub device **2450** emulates the ring communication topology by serially instructing the first device **2420** coupled to the first port of the hub device **2450** to provide a first distinctive identifier value, such as the device identifier value **2424** equal to "four," and instructs the second device **2440** coupled to the second port of the hub device **2450** to provide a second distinctive identifier value. The distinctive device identifier value of the second device **2440** is determined by the second device **2440**. In the particular illustrative embodiment of the FIG. **24**, the second device **2440** receives a serially propagated message **2404** via the hub device **2450**.

Emulating the ring topology for device enumeration enables the devices of the system **2400** to compute or select distinctive identifiers as described with respect to any of FIGS. **1-23** in a system having a physical hub architecture. The hub device **2450** may specifically route enumeration messages such that the devices **2420**, **2440**, and **2460** may select distinctive identifier values in an enumeration operation as described with respect to the ring topologies illustrated with respect FIGS. **2-4**, **6-8**, **9-11**, or any combination thereof. For example, in the ring communication topology emulation mode, the hub device **2450** forwards the first message **2402** to the first device **2420**. The first device **2420** receives the first message **2402** and generates a second message **2404**. The first device **2420** selects or otherwise determines a first device identifier value **2424** that may be stored at the first device **2420**. For example, the first device **2420** may select a distinctive device identifier value according to any of the techniques described with respect to FIGS. **1-23**. In the particular illustrative embodiment of FIG. **24**, the device identifier value **2424** of the first device **2420** is set to "four." The device identifier value **2424** is a distinctive identifier value that represents the first device **2420** for use by the host device **2410** to designate the first device **2420** as a message recipient in an addressed command.

The second message **2404** may be generated by modifying the first message **2402**. For example, the device identifier value **2424** of the first device **2420** may be inserted into the identifier value field of the first message **2402** as shown with respect to the second message **2404**. Thus, the second message **2404** may be the same as the first message **2402** except that the second message **2404** has a first identifier value set equal to "four" based on the device identifier value **2424** of the first device **2420**.

The second message **2404** is sent from the first device **2420** to the second device **2440** via the hub device **2450** operating in an emulated ring topology mode. The second device **2440** receives the second message **2404** and determines the second distinctive device identifier value **2444** of "five" by using the identifier value or values indicated as used by earlier devices (e.g. the value of "four" indicated as used by the first device **2410**) to generate or select the second distinctive identifier value **2444** to be distinctive from the identifier values indicated as used, such as via any technique described with respect to FIG. **1-23**. For example, the second device **2440** may implement an increment algorithm that generates a distinctive identifier value by incrementing the identifier value in the second message **2404**. Thus, the device identifier value **2444** may be set equal to "five" by incrementing the identifier value within the second message **2404**. The second device **2440** generates a third message **2406**, such as by modifying the second message **2404** to add an additional identifier value of "five" associated with the second device **2440**. Thus, the third message **2406** includes a first distinctive identifier value and a second distinctive identifier value. In a particular example, the first distinctive identifier value of "four" is associated with the first device **2420** and the second distinctive identifier value of "five" is associated with the second device **2440**.

The third message **2406** is forwarded serially in accordance with the emulated ring topology to the third device **2460** via the hub device **2450**. The third device **2460** receives the third message **2406** and generates a fourth message **2408**, such as by modifying the third message **2406**. In a similar manner, the fourth message **2408** may be generated by writing a distinctive device identifier value **2464** corresponding to the third device **2460** to a field in the payload portion of the fourth message **2408**. In a particular example, the third distinctive device identifier value **2464** may be incremented by the third device **2460** from the second device identifier value **2444** of the second device **2440**. As a particular example, the third distinctive device identifier value **2464** for the third device **2460** is set equal to "six" by incrementing the second distinctive device identifier value **2444** of "five." The fourth message **2408** includes multiple identifier values, including the first identifier value **2424** of "four," and the last generated identifier value, illustrated as the third identifier value **2464** of "six," thereby, representing multiple devices coupled to and detected by the hub device **2450**. While the fourth message **2408** is shown to include multiple identifier values including the first identifier value **2424** and the third identifier value **2464**, it should be understood that the fourth message **2408** may include the identifier values corresponding to each of the devices that has selected a distinctive identifier value and that is coupled to the host device **2410** via the hub device **2450**, such as the first identifier value **2424**, the second identifier value **2444**, and the third identifier value **2464**. Thus, two or more identifier values may be stored within a message to be forwarded by the hub device **2450** to the host device **2410**.

The hub device **2450** receives the fourth message **2408** from the third device **2460** and forwards the fourth message **2408** via the third port to the host device **2410**. The host device **2410**, upon receiving the fourth message **2408**, updates an enumeration table **2411** that identifies multiple ports and multiple identifier numbers. Alternatively, or in addition, the hub device **2450** may generate a table **2452** of device identifiers and provide content of the table **2452** to the host device **2410** for inclusion into the enumeration table **2411**. Although the enumeration table **2411** is identified as table within the host device **2410**, in other embodiments, the device identifiers may instead be stored in one or more other types of data structures accessible to the host device **2410**.

For example, during the ring communication topology emulation, as each message is received by the hub device

2450 from a respective one of the devices coupled thereto, the hub device 2450 may store distinctive identifier values in memory. Thus, as each of the devices 2420, 2440, and 2460 are identified by receipt of a message at the hub device 2450, the table 2452 within the memory may be dynamically adjusted to include additional information retrieved from each of these received messages.

As will be described with respect to FIG. 25, the hub device 2450 may include a controller that is operable in at least two different topology configurations. As shown in FIG. 24, the hub device 2450 may emulate a ring communication topology by serially instructing multiple devices coupled to respective ports to provide distinct identifier values and to send and forward messages including the distinctive identifier values in a ring topology mode. Alternatively, the hub device 2450 may operate in another mode where the hub device 2450 communicates with each of the devices coupled thereto in a configuration other than a ring. For example, the hub device 2450 may forward all received messages to each device attached to the hub device 2450 substantially concurrently, and each device may be responsible for identifying itself as an addressed (or otherwise allowed) recipient of the messages. The host device 2410 may be configured to function as a host to multiple devices, such as the first device 2420, the second device 2440, or the third device 2460, one or more of which may be non-volatile memory devices, such as flash memory devices. Thus, the system 2400 includes a host device 2410 to send an enumeration request to a hub device 2450 which may in turn recognize the enumeration request and emulate a ring communication topology to perform enumeration and to collect and store device identifier values for each device coupled to the hub device 2450 for reporting back to the host device 2410.

Although the devices 2440 and 2460 are illustrated as each generating a distinctive identifier value by incrementing the identifier value of the prior device along the emulated ring communication path, in other embodiments operation of the system 2400 is not limited by any particular technique of selecting or generating distinctive identifier values by the devices. For example, each device may instead select its distinctive identifier value by decrementing the identifier value of the prior device along the ring communication path, or by use of any of the other techniques described with respect to FIGS. 1-23. In addition, although the hub device 2450 is illustrated as storing the table 2452, in other embodiments the hub device 2450 may only store the table 2452 during the enumeration operation and may discard the table 2452 after the host device 2410 has received the device identifier data. Alternatively, the hub device 2450 may not generate the table 2452 or otherwise store any device identifier values and may instead forward enumeration messages along the emulated communication ring to the host device 2410 without retrieving device identifier values from the messages.

Referring to FIG. 25, a particular illustrative embodiment of the hub device 2450 of FIG. 24 is illustrated. The hub device 2450 includes a first port 2502, a second port 2504, and additional ports represented as an ith port 2506. Each port 2502-2506 may include a receive port and a transmit port. The hub device 2450 includes input/output (I/O) circuitry 2520, a controller 2540, and a memory 2552. The memory 2552 may be a volatile or non-volatile memory and includes executable instructions 2554 and a device identifier mapping table 2452. The controller 2540 includes a receiver 2542, a transmitter 2544, and a mode selector 2548. The controller 2540 also includes a message type identifier 2546 and a message generator 2550. The mode selector 2548 is coupled to the message type identifier 2546, which in turn receives messages from the receiver 2542. The message generator 2550 is coupled to the mode selector 2548. The message generator 2550 and the mode selector 2548 are each coupled to the transmitter 2544.

During operation, the I/O circuitry 2520 communicates with each of the ports 2502, 2504, 2506 to receive and to transmit data messages. The I/O circuitry 2520 may propagate received data 2530 to the receiver 2542 of the controller 2540. The received data 2530 is passed to the message type identifier 2546. The message type identifier 2546 evaluates the received data 2530 and determines the type of message received. The type of message determined by message type identifier 2546 is passed to the mode selector 2548. The mode selector 2548 identifies one of multiple communication modes, such as a ring emulation mode and a broadcast mode. The mode selector 2548 determines the selected mode based on the message type. For example, the mode selector 2548 may determine that the message type is an enumeration request and in response may set the mode to an emulated ring topology mode. The mode selector 2548 communicates the selected mode to the transmitter 2544 and to the message generator 2550. The message generator 2550 outputs messages to the transmitter 2544 for subsequent transmission external to the hub device 2450. The transmitted messages are formulated and communicated by the transmitter 2544 to the I/O circuitry 2520. For example, the transmitter 2544, responsive to the mode selector 2548 and to the message generator 2550, communicates control commands 2532 and data to be transmitted 2534. The control commands 2532 include, for example serial or parallel transmission commands. For example, parallel transmission is utilized in a broadcast mode, and serial transmission is used in the emulated ring topology mode. The data received by the I/O circuitry 2520 from the transmitter 2544 is communicated over one or more of the ports 2502, 2504, and 2506 to another device or to a host.

As each message is received by the controller 2540, certain aspects of the message, such as received distinctive device identifiers of devices coupled to the hub device 2450, may be retrieved by the controller 2540 and stored within the mapping table 2452 within the memory 2552. In addition, the controller 2540 may retrieve one or more of the executable instructions 2554 from the memory 2552 to execute various processes, such as mode selection, message type identification, and message generation. Thus, the controller 2540 is operative to perform operations, such as emulating a ring topology mode or operating in a broadcast mode with respect to the hub device 2450.

One or more of the message type identifier 2546, the mode selector 2548, and the message generator 2550 may be implemented as dedicated circuitry, firmware, processor-executed instructions, or any combination thereof. For example, the message type identifier 2546 may be implemented by one or more processors (not shown) executing instructions, such as a portion of the executable instructions 2554, to locate one or more fields of a header portion of a received message and compare a value of the located header field to one or more predetermined values. To illustrate, messages may comply with a standard such as a memory device protocol that specifies one or more header field locations and one or more predetermined values that may be used in the header fields. As examples, a header may include a device identifier field that stores one or more device identifiers of intended recipients or a broadcast indicator that designates all devices, such as an all-1's value. The message type identifier 2546 may compare the value read from the device identifier field to the broadcast indicator value to determine whether the received message is a broadcast message. For example, the message type identifier **2546** may perform a bitwise comparison, such as an AND or OR operation, may compare values arithmetically, such as by subtracting the values and comparing the result to zero, may perform a character-based or regular expression comparison operation, may use one or more other comparison techniques, or any combination thereof. The message type identifier **2546** may also compare an operational code or other message indicator of the header to identify whether the message is an enumeration message, such as via comparison to one or more predefined enumeration or initialization operational codes. In response to the message type identifier **2546** identifying a message as a broadcast message and as an enumeration message, the message type identifier **2546** may generate a value that causes the mode selector **2548** to select a ring communication mode. To illustrate, the message type identifier **2546** may store an output value in a register, onto a bus, or to a designated memory location to be retrieved by the mode selector **2548**.

The mode selector **2548** may be implemented as one or more processors executing instructions to retrieve the output value provided by the message type identifier **2546**, to compare the output value to one or more predetermined values, and to select a ring mode or another mode based on the comparison. The mode selector **2548** may generate a value that causes the control command **2532** to indicate a serial message propagation (e.g. sequential port-by-port message propagation) or a parallel message delivery (e.g. sending a received message at multiple or all ports substantially concurrently). In particular, the mode selector **2548** selects the ring emulation mode in response to the received message being a broadcast enumeration message. In other embodiments, the mode selector **2548** may also select the ring emulation mode in response to one or more other message types or for other operations, such as, for example, in response to a network management instruction to test device connectivity or network traffic.

The message generator **2550** may be implemented as one or more processors executing instructions to generate a message at least partially based on the received message. For example, the received message or content of the received message may be provided to the message generator **2550** via the message type identifier **2546** and the mode selector **2548**. Alternatively, the received message or content of the received message may be retrieved from a memory location that is accessible to the message selector **2550**, such as a message cache or queue coupled to the receiver **2542**. The message generator **2550** may include instructions that executed to write, remove, or change values of the received message to be sent as the transmit data **2534**. Alternatively, or in addition, the message generator **2550** may be executable to create messages to be sent as the transmit data **2534** based on a received message type or content, such as in accordance with programmed decision/action requirements or state machine operation, which may be at least partially based on a memory device communication protocol.

Although in the illustrative embodiment of FIG. **25**, the hub device **2450** includes a message type identifier **2546**, a mode selector **2548**, and a message generator **2550**, in other embodiments the hub device may not include one or more of the message type identifier **2546**, the mode selector **2548**, and the message generator **2550**. For example, in an alternative embodiment the hub device may not include a message generator, and instead messages that are received via one port and cached or temporarily stored at the I/O circuitry **2520** (e.g. at a receive buffer) or at the controller **2540** may be resent via one or more other ports without modification. As another example, in other embodiments, some or all of the operations described with respect to the message type identifier **2546**, the mode selector **2548**, the message generator **2550**, or any combination thereof may be performed by a single component, or otherwise divided among multiple components of the hub device.

FIG. **26** depicts a first embodiment of a method of operation of a hub device. The method may be performed at a hub device having a plurality of ports including a first port, a second port, and a third port. For example, the method may be performed by the hub device **2450** of FIGS. **24-25**.

A first message may be received from a host device a port of the hub device, at **2602**. The first message includes a broadcast indicator. For example, the first message may be the first message **2402** of FIG. **24** having the broadcast indicator (BST) in the message header.

A determination of whether the first message requests enumeration may be made, at **2604**. For example, the first message may include a header having message type information, and the message type information may be read from the header and compared to a predetermined value, at **2606**, to determine whether the first message requests enumeration. To illustrate, the predetermined value can include a predefined enumeration (ENUM) operational code (opcode) or other initialization (INIT) opcode that causes a receiving device to perform an enumeration operation, as illustrative, non-limiting examples.

In response to determining that the first message requests enumeration, at **2608**, a ring communication topology may be emulated by serially propagating messages including an enumeration indicator to a first device via a first port of the hub device and to a second device via a second port of the hub device, at **2610**. The first device may be a data storage device, such as the data storage devices illustrated in FIGS. **16-18**. For example, the first device may be a flash memory device, such as a flash memory card. As another example, the first device may be a data input-output device that uses a memory device protocol, such as the wireless communication device **1820** of FIG. **18**.

Using the hub device **2450** of FIGS. **24-25** as an illustrative example, the hub device **2450** may receive the first message **2402** from the host device **2410** via a port, such as the ith port **2506**. The first message **2402** may be provided to the I/O circuitry **2520** and provided to the controller **2540** as the received data **2530**. The message type identifier **2546** may read one or more predetermined fields from a header of the first message **2402** and perform one or more comparisons to determine whether the message is a broadcast message and whether the message requests enumeration. For example, the message type identifier **2546** may compare a destination identifier value from the header to an all-1's value that indicates a broadcast message and may also compare an opcode from the header to one or more predefined ENUM or INIT opcode values.

Continuing the illustrative example using the hub device **2450** of FIGS. **24-25**, the mode selector **2548** may determine whether to send the first message via serial transmission (e.g. to emulate a ring communication topology) or via parallel transmission (e.g. to broadcast to multiple devices concurrently). The determined transmission mode may be communicated to the I/O circuitry **2520** via the control command **2532** and the first message may be provided as the transmit data **2534**. When the mode selector **2548** selects a ring mode using serial transmission, such as when the first message is a broadcast enumeration message, the hub device **2450** may select or follow a predetermined pattern of serial messaging, such as first via the first port **2502**, next via the second port

2504, and may continue sequentially until all non-enumerated devices coupled to the hub device 2450 have received an enumeration message.

Emulating the ring communication topology enables the hub device to provide to the host device distinctive identifier values that are provided by the respective devices to be distinct from values provided by devices earlier in the ring. To illustrate, serially propagating messages can include sending the first message exclusively to the first device, at 2612. For example, the first message may be identified as including an enumeration indicator and may be sent to the first device without sending the first message to other devices coupled to the hub device. A second message may be received from the first device, at 2614. The second message may be identified as including the enumeration indicator or as otherwise being responsive to the first message. The second message may be the second message 2404 and may include a distinctive identifier value 2424 corresponding to the first device 2420.

Using the system 2400 of FIG. 24 as an illustrative example, the first message 2402 does not include a first distinctive identifier value corresponding to the first device 2420 or any other of the devices 2440 or 2460. The first device 2420 selects or computes the first distinctive identifier value and returns the second message 2404 to the hub device 2450. The second message 2404 includes the first distinctive identifier value 2424 of the first device, but does not include a second distinctive identifier value corresponding to the second device 2440 or a third distinctive identifier value corresponding to the third device 2460.

The second message may be sent to the second device, at 2616. The second message may be a response message, such as the response message 926 of FIG. 9. The second message may indicate the host device as an intended recipient and may be routed to the host device via the emulated communication ring. Alternatively, the second message may include the broadcast indicator, such as the second message 2404 of FIG. 24, but the second message may be sent exclusively to the second device rather than being broadcast to multiple devices concurrently.

A third message may be received from the second device, at 2618. The third message may be a response message, such as the response message 1046 of FIG. 10. The third message may include the first distinctive identifier value and the second distinctive identifier value. The third message may include the enumeration indicator to indicate the third message as an enumeration message.

The third message may be sent to a third device, at 2620. The third message may indicate the host device as an intended recipient and may be routed to the host device via the emulated communication ring including the third device. Alternatively, the third message may include the broadcast indicator, such as the third message 2406 of FIG. 24, but the third message may be sent exclusively to the third device rather than being broadcast to multiple devices concurrently. Although described as sent to a third device, when only the host device, the first device, and the second device are coupled to the hub device, the third message may be sent instead to the host device.

In response to determining that the first message does not request enumeration, at 2608, the first message may be selectively sent to the first device substantially concurrently with sending the first message to the second device, at 2622. To illustrate, selectively sending the first message to the first device substantially concurrently with sending the first message to the second device can include determining whether the first message includes the broadcast indicator, at 2624. For example, the message type identifier 2546 may read a destination value from a destination field of the message header and compare the destination value to a value indicating a broadcast message, such as an all-1's value, in an illustrative, non-limiting example. The first message may be sent to the first device substantially concurrently with sending the first message to the second device in response to determining that the first message includes the broadcast indicator, at 2626.

In an alternative embodiment, the first message may be sent to the first device substantially concurrently with sending the first message to the second device upon determining that the first message is not an enumeration message, independently of whether the first message is indicated as a broadcast message or not. For example, the hub device may send all non-enumeration messages to all devices coupled to hub device simultaneously so that each respective device can determine whether to read the message, such as by comparing a value in a destination identification field of a header of each message to the device's distinctive identification value, to a broadcast value, to one or more other values, or any combination thereof.

Although the hub device of the method of FIG. 26 is described as coupled to receive an enumeration request from a host device and serially propagating messages including an enumeration indicator among three other devices coupled to the hub devices, in other embodiments the hub device may serially propagate messages between only two devices coupled to the hub device or to more than three devices coupled to the hub device. For example, in a particular embodiment, a fourth message may be received from the third device. The fourth message may include the enumeration indicator. The fourth message may be sent to a fourth device. Serial propagation of messages may continue in a similar manner to enumerate additional devices that may be coupled to the hub device.

FIG. 27 depicts a second embodiment of a method of operation of a hub device. The method may be performed at a hub device having a plurality of ports including a first port, a second port, and a third port. For example, the method may be performed by the hub device 2450 of FIGS. 24-25.

The hub device may selectively emulate a ring topology in response to receiving an enumeration message from a host device. A first device coupled to the first port may be a first node of a ring and a second device coupled to the second port may be a second node of the ring. For example, an enumeration message from a host device may include a broadcast indicator, but instead of sending the enumeration message to multiple devices substantially concurrently, the hub device may instead propagate enumeration information around the ring so that the devices can select distinctive identifier values in a serial process where each device selects a distinct identifier value in turn according to the ring order resulting from each device's position along the communication path.

A table may be stored in a memory included within or accessible to the hub device. For example, the table may be the table 2452 of FIGS. 24-25. The table can include a first device identifier value for the first device and a second device identifier value for the second device. Upon initiating an enumeration operation, the table may be initially sized to store multiple device identifier values but may not include any stored identifier values.

A first enumeration message is sent to a first device via the first port, at 2702. The first enumeration message sent to the first device may not include any device identifier values, such as the first message 2452 of FIG. 24. The first device may be a data storage device, such as the data storage devices illustrated in FIGS. 16-18. For example, the first device may be a flash memory device, such as a flash memory card. As another example, the first device may be a data input-output device that uses a memory device protocol, such as the wireless communication device **1820** of FIG. **18**.

A second enumeration message is received from the first device, at **2704**. The second enumeration message includes a first device identifier value corresponding to the first device. For example, the second enumeration message may be the second message **2404** of FIG. **24** that is sent from the first device **2420** and received at the hub device **2450**.

The table may be dynamically modified in response to receiving the second enumeration message, at **2706**. As an illustrative, non-limiting example, the second enumeration message may be received at the first port **2502** of the hub device **2450** of FIG. **25** and provided to the controller **2540** as the received data **2530**. The controller **2540**, via dedicated circuitry, firmware, or processor executed instructions, may identify a payload portion of the second message and may read values stored in one or more fields of the payload portion. For example, the second message may have a header having a first predefined size, a payload portion having a second predefined size (e.g. a payload size indicated in a dedicated field of the header), and a CRC portion. The controller **2540** can locate a beginning of the payload portion by using the first predefined size of the header as a first offset from the message beginning and can identify an end of the payload portion by using the second predefined size of the payload as a second offset from the payload beginning. The controller **2540** can read data values from the payload portion and assign the data values to one or more data fields according to the message type. For example, if the message type identifier **2546** identifies the message as an enumeration message that is defined to include multiple four-bit device identifier values in the payload portion, the controller **2540** may sequentially read each four-bit value from the payload portion, compare the read value to one or more allowed or non-allowed values to determine whether the four-bit value is a valid device identifier value, and associate each valid device identifier value to a corresponding device or port of the hub device. It will be understood that the device identifier values may alternately include less than, or greater than, four bits.

The controller **2540** may initiate one or more data write operations at the memory **2552** to add the last valid device identifier value read from the payload portion to the table **2452** as the device identifier value associated with the port from which the message is received. For example, when the second message **2404** is received at the hub device **2450** via the first port **2502**, the controller **2540** may determine that the value "four" is the last valid device identifier value read from the payload portion of the second message and may initiate a data write operation to add the value of "four" in the row of the table **2453** corresponding to the first port **2502**.

Proceeding to **2708**, the second enumeration message is sent to a second device via the second port. A third enumeration message is received from the second device, at **2710**. The third enumeration message received from the second device includes a second device identifier value corresponding to the second device. For example, the third enumeration message may be the third enumeration message **2406** of FIG. **24**. The table may be dynamically modified in response to receiving the third enumeration message, at **2712**, such as in a manner similar to the manner described with respect to receiving the second enumeration message.

The first device identifier value and the second device identifier value are sent to a host device via the third port, at **2714**. For example, the hub device may send content stored at the table to the host device after the enumeration operation has completed. As another example, the hub device may send a last enumeration message to the host device as a last node on the emulated communication ring.

The first device identifier value and the second device identifier value enable the host device to address messages from the host device to the first device and to the second device. In some embodiments, the hub device may determine recipients of addressed messages and route received messages to the first and second devices based on the first and second identifier values. For example, messages received at the hub device may include one or more device identifier values as designated recipients. The hub device may direct the received messages to the corresponding port based on the device identifier values, such as by accessing the stored table of device identifier values and determining which port corresponds to a particular device identifier value. In other embodiments, the hub device may forward received messages to the first and second devices without determining addressed recipients of the messages.

Although the hub device **2450** of FIGS. **24-25** and the methods described with respect to FIGS. **26** and **27** are described with reference to enumeration of attached devices using a ring communication topology and broadcasting concurrent messages in a non-enumeration broadcast operation, the hub device **2450** may additionally be functional to receive and route messages according to one or more other topologies. For example, the hub device **2450** may support a hub-and-spoke topology, a star topology, a tree topology, one or more other topologies, or any combination thereof, for routing messages other than broadcast enumeration messages.

In addition, although operation of the hub device **2450** is described with respect to the system **2400** of FIG. **24**, the hub device **2450** may be included in any other systems that support auto-enumeration of devices to have distinctive identifier values. To illustrate, the hub device **2450** may be used in any of the systems depicted in FIGS. **1**, **2-4**, **5**, **6-8**, **9-11**, **12**, **15-18**, or any combination thereof. For example, the hub device **2450** may be used in the system **200** of FIG. **2** to couple the host device **210** to the devices **220**, **230**, and **240** to support device enumeration using a ring communication topology and to otherwise enable messaging between the host device **210** and the devices **220**, **230**, and **240** via one or more other communication topologies. As another example, the hub device **2450** may be used in place of one or more of the devices **220**, **230**, and **240** and may be operative to couple additional devices to the host device **210** while enabling each device to select a distinctive identifier value during an enumeration process.

In addition, or alternatively, hub devices configured to emulate the ring topology may be used in systems that include multiple layers of hubs. For example the second device **2440** of FIG. **24** may be a hub device that is configured to operate in a substantially similar manner as the hub device **2450** and that functions to enable communications between one or more other devices and the host device via the second (hub) device **2440** and the hub device **2450**. An enumeration message propagated from the host device **2410** to the second (hub) device **2440** would be serially propagated to all devices coupled to the second (hub) device **2440** along a second emulated ring communication path and the resulting device identifier value(s) would be provided to the hub device **2450**. For example, the second (hub) device **2440** may operate as if the hub device **2450** were a host device initiating an enumeration operation.

The illustrations of the embodiments described herein are intended to provide a general understanding of the various embodiments. Other embodiments may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. This disclosure is intended to cover any and all subsequent adaptations or variations of various embodiments. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the scope of the present disclosure. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

What is claimed is:

1. A method comprising:

at a hub device with a plurality of ports including a first port, a second port, and a third port, performing:

receiving a first message from a host device via the third port, the first message including a broadcast indicator;

in response to determining that the first message requests enumeration, emulating a ring communication topology by serially propagating messages including an enumeration indicator to a first device via the first port and to a second device via the second port; and

in response to determining that the first message does not request enumeration, selectively sending the first message to the first device substantially concurrently with sending the first message to the second device,

wherein emulating the ring communication topology enables the hub device to provide a first distinctive identifier value of the first device and a second distinctive identifier value of the second device to the host device.

2. The method of claim **1**, wherein the first message includes a header having message type information, and further comprising comparing the message type information to a predetermined value to determine whether the first message requests the enumeration.

3. The method of claim **1**, wherein selectively sending the first message to the first device substantially concurrently with sending the first message to the second device includes:

determining whether the first message includes the broadcast indicator; and

sending the first message to the first device substantially concurrently with sending the first message to the second device in response to determining that the first message includes the broadcast indicator.

4. The method of claim **1**, wherein serially propagating messages includes:

sending the first message to the first device, the first message identified as including the enumeration indicator;

receiving a second message from the first device, the second message identified as including the enumeration indicator; and

sending the second message to the second device.

5. The method of claim **4**, wherein the first message does not include the first distinctive identifier value and wherein the second message includes the first distinctive identifier value but does not include the second distinctive identifier value.

6. The method of claim **5**, wherein the second message includes the broadcast indicator and wherein the second message is sent exclusively to the second device, the method further comprising:

receiving a third message from the second device, the third message including the enumeration indicator; and

sending the third message to a third device.

7. The method of claim **6**, further comprising:

receiving a fourth message from the third device, the fourth message including the enumeration indicator; and

sending the fourth message to a fourth device.

8. The method of claim **6**, wherein the third message includes the first distinctive identifier value and the second distinctive identifier value.

9. The method of claim **1**, wherein the first device is a flash memory device.

10. The method of claim **1**, wherein the first device is a data input-output device that uses a memory device protocol.

11. The method of claim **1**, wherein serially propagating messages includes:

sending the first message to the first device, the first message identified as including the enumeration indicator;

receiving a second message from the first device, the second message identified as including the enumeration indicator; and

sending the second message to the second device, wherein the second message includes the broadcast indicator.

12. A method comprising:

at a hub device with a plurality of ports including a first port, a second port, and a third port, performing:

sending a first enumeration message to a first device via the first port;

receiving a second enumeration message from the first device, wherein the second enumeration message includes a first device identifier value corresponding to the first device;

sending the second enumeration message to a second device via the second port;

receiving a third enumeration message from the second device, wherein the third enumeration message received from the second device includes a second device identifier value corresponding to the second device; and

sending the first device identifier value and the second device identifier value to a host device via the third port in a single message,

wherein the first device identifier value and the second device identifier value enable the host device to address messages from the host device to the first device and to the second device.

13. The method of claim **12**, wherein the first enumeration message sent to the first device does not include any device identifier values.

14. The method of claim **12**, wherein the hub device selectively emulates a ring topology in response to receiving an enumeration message from the host device, wherein the first device is a first node of a ring and the second device is a second node of the ring.

15. The method of claim **14**, wherein the enumeration message from the host device includes a broadcast indicator.

16. The method of claim **12**, further comprising storing a table in a memory, the table including the first device identifier value and the second device identifier value.

17. The method of claim **16**, further comprising dynamically modifying the table in response to receiving the second enumeration message and the third enumeration message.

18. The method of claim **12**, wherein the first device is a flash memory device.

19. The method of claim **12**, wherein the first device is a data input-output device that uses a memory device protocol.

20. A hub device comprising:

a plurality of ports including a first port, a second port, and a third port; and

a controller coupled to the first port, the second port, and the third port, wherein the controller is configured to:

receive a first message from a host device via the third port, the first message including a broadcast indicator;

in response to determining that the first message requests enumeration, emulate a ring communication topology by serially instructing a first device coupled to the first port to provide a first distinctive identifier value and instructing a second device coupled to the second port to provide a second distinctive identifier value; and

in response to determining that the first message does not request enumeration, initiate sending the first message to the first device via the first port and sending the first message to the second device via the second port substantially concurrently.

21. The hub device of claim 20, further comprising a memory and wherein the controller stores the first device identifier and the second device identifier in the memory.

22. The hub device of claim 20, wherein the first device is a flash memory device.

23. A method of enumerating devices coupled to a memory device interface, the method comprising:

at a host device with a memory device interface, the memory device interface operatively coupled to multiple devices including a first device and a second device, the first device in a first position to receive messages from the host device along a communication path, the second device in a last position to receive the messages from the host device along the communication path, performing:

receiving an enumeration message including a set of device identifier fields, the set of device identifier fields including a sequentially first identifier field containing a first device self-generated identifier value and a sequentially last identifier field containing a second device self-generated identifier value;

reading the first device self-generated identifier value from the sequentially first identifier field;

recording the first device self-generated identifier value as corresponding to the first device in the first position along the communication path;

reading the second device self-generated identifier value from the sequentially last identifier field; and

recording the second device self-generated identifier value as corresponding to the second device in the last position along the communication path.

24. The method of claim 23, further comprising recording a device self-generated identifier value of each device of the multiple devices other than the first device and the second device based on a relative position of each device along the communication path.

25. The method of claim 23, wherein the sequentially first identifier field corresponds to the first position along the communication path and wherein the sequentially last identifier field corresponds to the last position along the communication path.

26. A host device comprising:

a memory device interface, the memory device interface operatively coupled to multiple devices including a first device and a second device, the first device in a first position to receive messages from the host device along a communication path, the second device in a last position to receive the messages from the host device along the communication path; and

a controller coupled to the memory device interface, the controller operative to:

receive an enumeration message including a set of device identifier fields, the set of device identifier fields including a sequentially first identifier field containing a first device self-generated identifier value and a sequentially last identifier field containing a second device self-generated identifier value;

read the first device self-generated identifier value from the sequentially first identifier field;

record the first device self-generated identifier value as corresponding to the first device in the first position along the communication path;

read the second device self-generated identifier value from the sequentially last identifier field; and

record the second device self-generated identifier value as corresponding to the second device in the last position along the communication path.

27. The host device of claim 26, wherein the controller is further operative to record a device self-generated identifier value of each device of the multiple devices other than the first device and the second device based on a relative position of each device along the communication path.

28. The host device of claim 26, wherein the sequentially first identifier field corresponds to the first position along the communication path and wherein the sequentially last identifier field corresponds to the last position along the communication path.

29. A method of enumerating devices, the method comprising:

at a host device with a memory device interface, the memory device interface operatively coupled to multiple devices including a first device in a first position to receive messages from the host device along a communication path, the first position to receive the messages prior to all other devices of the multiple devices, performing:

sending a first enumeration message prior to receiving, from any of the multiple devices, an identifier value indicated as being used,

wherein the first enumeration message comprises an instruction to direct the first device to select a first device identifier value according to a selection rule, wherein the selection rule is selected from multiple selection rules; and

receiving a second enumeration message indicating the first device identifier value as being used by the first device,

wherein the first identifier value enables the host device to specifically identify the first device as a message recipient.

30. The method of claim 29, wherein the first enumeration message includes a parameter to direct the first device to use a particular selection rule based on the parameter.

31. The method of claim 29, wherein the first enumeration message directs selection of the first device identifier value as a random or pseudo-random value.

32. The method of claim 29, wherein the first enumeration message includes an identifier value threshold, and wherein the first enumeration message directs selection of the first device identifier value as an offset added to the identifier value threshold.

33. A host device comprising:

a memory device interface configured to operatively couple the host device to multiple devices, the multiple devices including a first device in a first position to receive messages from the host device along a communication path, the first position to receive the messages prior to all other devices of the multiple devices; and

a controller configured to send an enumeration message prior to receiving, from any of the multiple devices, an identifier value indicated as being used, wherein the enumeration message comprises an instruction to direct the first device to select a first device identifier value according to a selection rule, wherein the selection rule is selected from multiple selection rules, and

wherein the first identifier value enables the host device to specifically identify the first device as a message recipient.

34. The host device of claim **33**, wherein the enumeration message includes a parameter to direct the first device to use a particular selection rule based on the parameter.

35. The host device of claim **33**, wherein the enumeration message directs selection of the first device identifier value as a random or pseudo-random value.

36. The host device of claim **33**, wherein the enumeration message includes an identifier value threshold, and wherein the first enumeration message directs selection of the first device identifier value as an offset added to the identifier value threshold.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,312,088 B2
APPLICATION NO. : 12/561122
DATED : November 13, 2012
INVENTOR(S) : Yoseph Pinto

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

Item (75), correct the spelling of the Inventor's name from Yosi Pinto to Yoseph Pinto

Signed and Sealed this
Thirteenth Day of October, 2020

Andrei Iancu

Andrei Iancu
Director of the United States Patent and Trademark Office